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Memoirs of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

VOL. XLV. No. 2.

SOLENOGASTRES FROM THE EASTERN
COAST OF NORTH AMERICA.

By HAROLD HEATH.

WITH FOURTEEN PLATES.

[Published by Permission of E. LESTER JONES, Superintendent U. S. Coast and Geodetic Survey and of H. M. SMITH,
U. S. Commissioner of Fish and Fisheries].

CAMBRIDGE, U. S. A.:

Printed for the Museum.

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SOLENOGASTRES FROM THE EASTERN COAST OF NORTH AMERICA.

INTRODUCTION.

The present report deals with a collection of upwards of one hundred and twenty-five Solenogastres dredged at various times by Coast Survey or U. S. Fish Commission vessels along the eastern coast of the United States. The greater number of these were placed at my disposal by the late Mr. Alexander Agassiz, who generously granted permission to include the descriptions of additional species based upon material kindly forwarded by Prof. A. E. Verrill and by the officials of the National Museum.

The territory embraced by these explorations, with the exception of a single station off the south coast of Florida, another in the Gulf of St. Lawrence and a third off the coast of Newfoundland, extends from the Gulf of Maine on the north to the mouth of Chesapeake Bay on the south. The larger number of dredge hauls were made along shore in comparatively shallow water; thirty-four were at depths ranging from one hundred to five hundred fathoms, three were from five hundred to one thousand fathoms, two from one thousand to fifteen hundred fathoms and one from seventeen hundred and fifty-three fathoms. The appended table indicates the habitat with greater exactness. The following abbreviations have been employed to indicate the vessels engaged: A Albatross, B Bache, Be Blake, Bt Bluelight, Fk Fishhawk, Sp Speedwell.

Species	Station	Number of Specimens	Depth in Fathoms	Locality					
				Lat. N.			Long. W.		
Chaetoderma bacillum	2076A	3	906	41	13	—	66	—	50 200 m. E. of Cape Cod.
“ caudatum	2588A	8	479	39	02	—	72	36	— 240 m. E. of Cape May.
“ lucidum	2212A	15	428	39	59	30	70	30	45 240m.N.E.of Cape May.
“ “	2588A	15	479	39	02	—	72	36	— 240 m. E. of Cape May.

Species	Station	Number of Specimens	Depth in Fathoms	Locality						
				Lat. N.			Long. W.			
				°	'	"	°	'	"	
<i>Chaetoderma nitidulum</i>	2458A	50	89	46	48	30	52	34	—	S. E. of Newfoundland.
“ “	20B		95	43	01	—	70	10	—	Near Boon Is. Light, Me.
“ “	31B		56	42	19	—	70	29	—	Massachusetts Bay.
“ “	38-43B		27-68	42	57	—	70	35	—	Gulf of Maine.
“ “	62-65B		42-58	43	38	—	69	22	—	Gulf of Maine.
“ “	69B		32	43	11	—	69	35	—	Off S. coast of Maine.
“ “	892Fk.		36	40	33	—	70	45	—	Off Martha's Vineyard.
“ “	895Fk.		238	39	56	30	70	59	45	Off Martha's Vineyard.
“ “	898Fk.		300	37	24	—	74	17	—	Chesapeake Bay, Mass.
“ “	943Fk.		157	40	—	—	71	14	30	Off Martha's Vineyard.
“ “	18Sp.		45	42	29	—	70	38	—	Near Salem, Mass.
“ “	293Sp.		27	42	03	—	70	19	—	Cape Cod Bay, Mass.
“ “	296Sp.		26	42	02	—	70	26	—	Cape Cod Bay, Mass.
“ “	301Sp.		27	42	01	—	70	20	—	Cape Cod Bay, Mass.
“ “	317Sp.		25	42	02	—	70	14	—	Cape Cod Bay, Mass.
“ “	322Sp.		67	42	12	—	70	01	—	Off Cape Cod, Mass.
“ “	350Sp.		31	42	08	—	70	25	—	Massachusetts Bay.
“ squamosum	2534A	1	1234	40	01	—	67	29	15	200 m. S.E. of Cape Cod.
“ vadorum	—	5	—	—	—	—	—	—	—	Casco Bay, Me.
“ “	3B	1	64	43	38	—	69	17	—	Off S. coast of Maine.
“ “	20B	1	95	43	10	—	70	10	—	Near Boon Is. Light, Me.
“ “	317Sp.	1	25	42	02	—	70	14	—	Cape Cod Bay, Mass.
<i>Neomenia verrilli</i>	—	1	313	—	—	—	—	—	—	Gulf of St. Lawrence.
<i>Pronomenia acuminata</i>	5Be	1	150-229	24	15	—	82	13	—	Straits of Florida.
“ “	893Fk.	1	372	39	52	20	70	58	—	S. of Martha's Vineyard.
“ “	2547A	1	390	39	54	30	70	20	—	S. of Rhode Island.
<i>Dorymenia peroneopsis</i>	2715A	1	1753	38	29	30	70	54	30	S. of Martha's Vineyard.
<i>Strophomenia agassizi</i>	2046A	5	407	40	02	49	68	49	—	S.E. of Nantucket, Mass.
“ “	2528A	4	677	41	47	—	65	37	30	E. of Cape Cod, Mass.
<i>Nierstrassia fragile</i>	2588A	11	479	39	02	—	72	36	—	Off coast of New Jersey.

Up to the present time very few Solenogastres have been collected along the Atlantic coast of North America. *Chaetoderma canadense* Nierstr. has been taken off Port Hood, Canada, *Neomenia carinata* Wiren came from the North Atlantic, and *Neomenia microsolen* Koren & Danielson is recorded from the West Indies; but none of these species is represented in the present collection, and accordingly nothing further can be said regarding their geographical range. The discovery of *Chaetoderma nitidulum* off the New England coast indicates that this species is relatively abundant throughout the North Atlantic Ocean north of the fortieth parallel. *Pronomenia acuminata* was originally described from specimens collected in the West Indies. The material in hand extends its distribution along the Florida coast and the Atlantic seaboard as far north as Rhode Island. Other species in the present collection are new, and thus far their known range is very limited.

CLASSIFICATION.

Judging from the material already described, it is evident that not only is the genus *Chaetoderma* very widely distributed, but the individual species are difficult to differentiate, especially where we are compelled to rely solely upon descriptions and figures. Externally and internally there is considerable variation within a given species, and suitable diagnostic characters are difficult to discover. The relations of the gut to the somatic musculature and the ventral blood sinus at the junction of the pro- and metathorax are of considerable value in the specimens I have thus far examined, and with figures of this region and others of characteristic sections it is believed that it will be possible, without great difficulty, to recognize the species described in this and the earlier Pacific Ocean report.

The validity of the genus *Dorymenia* Heath has been questioned by certain investigators, but the discovery of a second species, with all of the characteristic features of the first (*Dorymenia acuta*), indicates that the genus was well founded.

Order APLACOPHORA v. Ihering.

Suborder I. Chaetodermatina Simroth.

Spiculose integument continuous all around the body.

Chaetodermatidae, p. 189.

Suborder II. Neomeniina Simroth.

Spiculose integument interrupted beneath by a longitudinal ventral furrow.

Neomeniidae, p. 191.

Proneomeniidae, p. 191.

Dondersiidae, p. 192.

CHAETODERMATIDAE SIMROTH.

Opening of mouth and anal chamber terminal. Body with more or less sharply marked regions. Ventral furrow and fold lacking. Two highly developed plume-like gills. Radula distichous, polyserial or strongly reduced to a large unpaired cuticular tooth. The mid-gut possesses, in most cases, a well-

developed digestive gland. Copulatory apparatus lacking. Coelomoducts remain separate. Cuticle thin, spicules flat, often needle-form, but solid. Inhabit bottom ooze.

CHAETODERMA LOVEN, 1845.

Body vermiform, without ventral groove; mouth and anal chamber terminal. Two gills. Sexes separate. Radula reduced to conical peg. Type of genus

C. nitidulum LOVEN.

Head, cylindrical or pear-shaped, bounded posteriorly by a circular groove. Spines with keel absent or but slightly developed. North Atlantic (p. 193).

C. caudatum, sp. nov.

Length from 3.3 mm. to 7.75 by 1.3 mm. greatest diameter. Greatest thickness of body in preabdomen; the postabdominal region narrows abruptly to a tail-like appendage. Northeast coast of the United States at a depth of 428–499 fathoms. (p. 193).

C. vadorum, sp. nov.

Length 12.5 mm. by 1.1 thickness of preabdomen to 15.2 by 1.45 mm. Spines strongly keeled and at junction of metathorax and abdomen measure from 0.1 to 0.14 mm. in length. Mouth occupies a cleft in the buccal plate. Off coast of Maine at a depth of 25–95 fathoms. (p. 195).

C. lucidum, sp. nov.

Body size variable, ranging from 1.2 mm. width by 11.25 length to 0.75 mm. width by 25 mm. length. Spines with keel slight or undeveloped, with average length on preabdomen of 0.12 mm. Mouth occupies a cleft in the buccal plate. Off coast of New Jersey at 428–479 fathoms depth. (p. 198).

C. bacillum, sp. nov.

Length 11–17 mm. length by 0.9–1.07 mm. greatest diameter. Spines moderately keeled with a length of 0.11–0.16 mm. at the junction of the pro- and metathorax. Mouth perforates the buccal plate. Off the Massachusetts coast at a depth of 900 fathoms. (p. 201).

C. squamosum, sp. nov.

Length 25.7 mm. length by 1.3 mm. greatest thickness. Mouth pierces the buccal plate. Spines unusually thin, weakly keeled. Off Massachusetts at 1,234 fathoms depth. (p. 204).

NEOMENIIDAE SIMROTH.

Body compressed, more or less crescent-shaped, without distinct divisions. Index 7 at most. Opening of atrium ventral, of the anal chamber ventral or terminal. Ventral furrow present, usually with several folds. Cuticle sometimes comparatively thick, spines mostly needle-like, flat, grooved or hollow. A circlet of gills in the anal chamber. Radula and salivary glands usually lacking. Epidermal papillae, of simple structure, usually present. Fore gut protrusible, coelomoducts separate or united to form a shell gland or copulatory organ. Digestive gland lacking. Penial spines usual present. Free, creeping about over bottom.

NEOMENIA TULLBERG, 1875.

Body thick-set and usually compressed laterally, 2-3 cm. long, with anterior and posterior ends similarly shaped. Cloacal opening subterminal. Ventral fold present with the groove extending to the cloacal chamber. Spicules needle- or spearhead-shaped, projecting from the cuticle. Broad stalked papillae present. Branchial folds in the cloacal chamber. Copulatory spines usually present. Radula absent. Type of genus, *N. carinata*.

N. verrilli, sp. nov.

Body thick-set, unkeeled, 25 mm. in length by 8 mm. greatest thickness. 8 ventral folds, 30-40 branchial folds. Accessory copulatory apparatus present. Gulf of St. Lawrence, 313 fathoms. (p. 206).

PRONEOMENIIDAE SIMROTH.

Worm-like. Radula distichous or polystichous, sometimes lacking. Salivary glands tubular, lobed or lacking. Cuticle thick, spicules mostly needle-like in several layers. Epidermal papillae present. Gills usually lacking. Coelomoducts usually united into a shell gland, sometimes separated. Copulatory spicules may be present. Free living, partly or entirely parasitic.

PRONEOMENIA HUBRECHT, 1880.

Body elongated, vermiform, the length 9-50 times the diameter. Cloacal opening ventral. Foot present, the groove passing into the cloacal chamber. Cuticle thick with crowded spicules in several layers. No gills. Radula

multidentate. Two salivary glands. Copulatory spines present or absent. Type of genus, *P. sluiteri*.

P. acuminata WIREN.

Length index 9.3. Radula present. (p. 215).

DORYMENIA HEATH, 1911.

Vermiform, body terminating posteriorly in a finger-shaped elongation. Radula multidentate with 9–51 longitudinal rows of from 9–22 teeth in each transverse row. One pair of seminal receptacles. A pair of long copulatory spicules closely associated with a pair of globular coeca or deep pits likewise opening separately into the cloacal chamber. Type of genus, *D. acula*.

D. peroneopsis, sp. nov.

Body 25 mm. in length by 2 mm. in greatest thickness. Radula with 9 longitudinal rows of teeth and 22 teeth in each transverse row. Accessory copulatory apparatus present. Off the Massachusetts coast at a depth of 1,753 fms. (p. 222).

STROPHOMENIA PRUVOT, 1899.

Body elongated, cylindrical, the thick cuticle penetrated by acicular spicules and closely crowded vesicular papillae. Radula and salivary ducts present. Two distinct genital openings into the cloacal chamber usually present. Type of genus, *S. lacazei*.

S. agassizi, sp. nov.

Worm-like, 22–37 mm. in length by 1.1–1.5 mm. average diameter. Papillae stalked, numerous; spicules needle-like. Radula very small. Ventral salivary glands tubular. Nine pairs of seminal receptacles. Off Massachusetts coast, 677 fms. (p. 229).

DONDERSIIDAE SIMROTH.

Body often worm-like; cuticle thin; spines flat and solid. Papillae lacking. Radula distichous, monoserial or lacking. Salivary glands globular, sac- or tube-like. Gill folds lacking. Coelomoducts united or separate. Copulatory apparatus may be present. Ventral fold and furrow may be absent. Living free upon corals, etc.

NIERSTRASSIA, gen. nov.

Body short, 2.5–5 mm. in length by 0.75–1 mm. thick. Single layer of leaf-like keeled spines as in *Chaetoderma*; no papillae. Epithelium of atrium (?) composed of long, slender cells without cirri and ciliated ridges. Radula distichous, 15 transverse rows. Dorsal salivary glands diffuse, ventral small, lobulated. Coelomoducts with three pairs of diverticula, two bundles of copulatory spines (5 in each bundle) opening into terminal part of shell gland. Reproductive opening on large papilla. Posterior walls of cloaca with 5–6 glandular folds. Type of genus *N. fragile*, sp. nov. with characters of the genus. Off New Jersey coast, 479 fms. (p. 235).

DESCRIPTION OF SPECIES.

Chaetoderma nitidulum LOVEN.

This species is represented by over fifty specimens dredged from various comparatively shallow water stations between Newfoundland on the north to Virginia on the south. Whether this last named locality represents the southernmost limit of distribution it is impossible to state as the work of exploration south of 37° north latitude is largely confined to deep water. In the present case the bathymetrical distribution ranges from 25 to 300 fathoms; elsewhere it is reported to range from 25 to 2,250 meters. Specimens in the present collection have been taken at the stations noted on page 183.

A careful comparison of these western Atlantic specimens with the descriptions given by various authors and with a single individual from the Kara Sea discloses no essential differences. One of the Atlantic specimens is unique in being monocious. Throughout its entire extent the gonad is distended with vast numbers of spermatozoa, mature and in various stages of development. The ova are also in different stages of growth, and roughly speaking are developed on the surface of an inconspicuous septum separating the halves of the ovotestis, while the sperms arise from more lateral positions.

Chaetoderma caudatum, sp. nov.

Eight specimens of this species were dredged off the coast of New Jersey (Sta. 2588A) in 479 fathoms of water where the bottom consisted of green mud. In every case the posterior end of the body rapidly narrows in the vicinity of the cloaca to form a tail-like appendage of approximately even calibre through-

out. The largest specimen (Plate 9, fig. 1), measures 7.75 mm. in length by 1.3 in greatest diameter, while the smallest is 3.3 by .75 mm. In several individuals the anterior end of the prothorax is considerably swollen, giving the entire body a decided trumpet-shape.

The color, especially of the older individuals, is a slaty gray in the mesothorax and the posterior part of the prothorax, owing to the dark colored liver showing through the translucent body wall. The postabdomen is of the usual light yellow tint save the posterior half or third which is very dark brown owing to an incrustation consisting apparently of faecal matter or substances from the coelomoducts. A dark brown or black band encircles the prothorax and this peculiarity together with the shape of the body readily distinguishes the species.

The dorsal sense organ, in the form of a deep groove, holds the customary position at the posterior end of the body, but owing to the overarching spines it is in large measure invisible in whole specimens. In sections it is seen to be composed of slender cells whose general arrangement and appearance are typical of the genus.

The mouth opens through the centre of the buccal plate whose general appearance is represented (Plate 9, fig. 4). Between this point and the anterior border of the brain the buccal tube is of moderate size, is folded to form four or five longitudinal ridges, and supports a considerable number of gland cells attached to its outer surface. These last named organs, grouped into lobules (Plate 8, fig. 7), whose general size and shape depend upon the spaces between the longitudinal and radial muscles of the buccal tube, are composed of small cells containing after treatment with Delafield's haematoxylin an abundance of some golden yellow, finely granular secretion.

The subradular organ is moderately distinct and the tooth (Plate 9, fig. 5) of average size. Behind the radula the canal rapidly narrows, becomes thick walled and the component cells, slender in form, are filled with a dense, finely granular secretion. This condition of affairs continues to the opening borne on the summit of a short papilla (Plate 8, fig. 10) projecting into the gastric cavity. The stomach is a capacious sac, with highly folded walls especially in the neighborhood of the oesophageal opening where the cells are packed with a finely granular, yellowish secretion. In the vicinity of the bile duct the walls are much thinner, nearly smooth and the epithelial cells are approximately cubical and contain but a small quantity of secretory products.

The liver presents in general the usual appearance, possessing yellowish brown Körnerzellen and moderately staining Keulenzellen. The intestine,

with walls of the usual character, pursues its course to the end of the preabdomen where it becomes unusually narrow and contorted before opening in the customary fashion into the cloacal chamber. Food products, among them relatively long and slender tubular fragments of some unknown organism, are present in considerable quantities in the stomach and the proximal part of the hepato-pancreas and in a more or less digested condition throughout the intestine.

So far as could be determined the circulatory system is typical of the genus. As noted in connection with the reproductive system the aorta at its origin is unusually heavy walled and of large calibre. In the region of the gonad its walls become thinner yet distinct so that they may be traced readily to the neighborhood of the radula where it disappears as a distinct vessel.

The nervous system is very distinct and has been examined with more than usual care, but in all essential respects it is practically the same as in *C. attenuata* for example.

The single specimen sectioned is a female with the sex gland, filled with ova in all stages of development, holding the customary position. At the junction of the preabdomen with the tail-like postabdomen the ovary rapidly narrows to form the paired canals leading into the pericardium. These, however, are of unusual extent, traversing almost the entire extent of the postabdomen, and are separated from each other by the large dorsal aorta (Plate 8, fig. 11) whose walls in this region are relatively heavy. In the neighborhood of the pericardial cavity they become somewhat enlarged but otherwise they exhibit no unusual features.

The pericardium is of moderate size and the coelomoducts open in the usual position (Plate 9, fig. 6) by very distinct, ciliated funnels connected with a short non-glandular section directed anteriorly. At the level of the dorsal commissure they unite with the glandular portion which though it is of large size relatively, lacks the sacculations and tortuous course characteristic of larger species and passes directly backward to open at the usual point in the cloacal chamber. The cells lining this main division of the canals are composed of highly vacuolated protoplasm frequently in the process of liberating its products by means of constriction of the distal end of each cell.

Chaetoderma vadorum, sp. nov.

One specimen (Plate 13, fig. 1) of this species was taken off the south coast of Maine (Sta. 3B) at a depth of 64 fms., another from the same general locality

(Sta. 20B) was dredged at a depth of 95 fms., and a third came from Cape Cod Bay, Mass. (Sta. 317 sp.) at a depth of 25 fms. Two additional specimens, of approximately the same size, bear the label "Casco Bay, Maine, U. S. Fish Com., Aug. 5th. 1873." No other data are forthcoming but it may be assumed that they are shallow water forms. The length of the largest (sectioned) specimen was 15.2 mm. with a diameter through the abdomen (Wiren) of 1.45 mm.; the smaller specimen is 12.5 mm. long by 1.1 in diameter. The color is light brownish yellow though this may be due to long preservation or to tannin from the cork. The buccal plate (Plate 13, fig. 2) is somewhat distorted, but appears to be elliptical in outline or broadly shield-shaped with the mouth occupying a deep indentation in the dorsal two thirds.

The spines examined were taken from the neighborhood of the union of the metathorax and abdomen, and range in length from 0.1 to 0.14 mm. They present the usual spearhead appearance (Plate 12, fig. 3), and are strongly keeled throughout nearly their entire length. The cells composing the hypodermal layer (Plate 13, fig. 8) comprise two distinct types, the matrix cells of the spicules, and those probably responsible for the development of the cuticle. The first exist in the form of flattened disc-like bodies attached to the basal portion of the spine, and indicate that in this genus every spicule is the product of a single cell. The cells of the second class possess spherical nuclei, and a columnar form though as a general rule they are without clearly defined boundaries.

In the region of the union of the pro- and metathorax especially the hypodermal layer is seen to rest upon a felt-work of connective-tissue fibres, forming a species of basement membrane that stains intensely in haematoxylin. A short distance removed from this region the meshwork becomes less compact and less darkly staining. Under fairly high magnification fibres may be seen to traverse the underlying somatic muscles and to enter the basement membrane whose elements they resemble closely; but in no case have they been seen to extend into the hypodermal layer, and it may be added the material appears to be excellently preserved.

As usual the buccal plate is composed of a heavy cuticular layer (Plate 13, fig. 4) resting upon the hypodermis in which the cell elements are very indefinitely defined. About the margins of the plate the cells possess fairly distinct nuclei and cell boundaries, but in the more central regions bordering the mouth they become distorted, owing apparently to numerous nerve and muscle fibres that either attach to or pass between them to the cuticular plate.

Darkly staining ductules open to the exterior close to the margins of the plate, and for the first time in my experience have been traced to definite cells.

In sections these are seen to occupy a position adjacent to the buccal tube, and along the path traversed by the nerves destined to the buccal plate and originating in the great precerebral nerve masses (buccal ganglia of Wiren). In several other species of the genus ductules lead to cells in the same general position, but the lack of a clearly defined secretion in these cells and owing to their resemblance to ganglion cells it has never been possible heretofore to make the identification certain. In the light of the state of affairs in the present case it is altogether probable that gland cells are normally present and in the position described above.

These gland cells are usually arranged in the form of lobules, though separate cells are occasionally met with in the neighborhood of the buccal plate. Each, in a fully developed condition contains numbers of darkly staining granules, though not in sufficient numbers to mask the nucleus. This last named body occupies a central position, and contains a well-defined though faintly staining nucleolus. In a few instances the ductules perforate the margins of the buccal plate; more generally they pass to the exterior without the borders of the plate but in close proximity to it.

As noted previously the mouth occupies a cleft in the buccal plate, and sections show that it leads into a canal of average dimensions and with typical relations. Generally speaking the epithelial lining rests upon a circular muscle layer, but as this is pierced by numerous radial or diagonal fibres the line of demarcation is by no means sharp, a state of affairs that is accentuated by the presence of several glands. These last named organs (Plate 12, fig. 2), in the form of lobules, encircle the tube and are in all stages of glandular activity. Those in an inactive state bear a fairly close resemblance to the neighboring ganglion cells, but in a fully developed condition they become distended with a vacuolated, moderately staining secretion that escapes into the buccal tube or pharynx by intercellular canals, though these are usually difficult to demonstrate.

The radula of this genus, together with its supports and muscles, is a remarkably constant structure, and this species is no exception to the rule (Plate 12, fig. 1), there being no marked characteristics of diagnostic value.

Immediately posterior to the radula the digestive tract narrows rapidly, and becomes elliptical in outline (Plate 12, figs. 9, 12). The cells of the lining are greatly elongated and glandular, the secretion appearing as a finely granular, moderately staining mass that may in rare instances become so abundant and closely packed that it appears to be homogeneous. This state of affairs rapidly changes as the canal is followed backward. The cells become lower, and in most instances have been dislodged, evidently due to the decreased pressure attendant upon coming to the surface. Where they have remained they are

likewise glandular, and continue in this condition for a considerable distance beyond the union of the pro- and metathorax (Plate 12, fig. 14) where the alimentary canal attains a greater diameter (Plate 12, fig. 5). Sections were not made of the mid region of the body. Posteriorly the intestine pursues the usual course and opens in typical fashion into the cloacal chamber.

The cloacal cavity, so far as shape and relations are concerned, is not unusual, but its epithelial lining, especially near the posterior end of the animal, is highly glandular, the cells staining intensely in haematoxylin. Gland cells with similar staining reaction occur in the branchiae, and are limited to very definite zones (Plate 12, fig. 13). A comparatively small number occur in the external epithelial layer immediately dorsal to the dorsal branchial sinus, and a much larger proportion is imbedded in the lamellae, forming in sections a horizontal band passing through the dorsal limit of the ventral gill retractors.

The circulatory system presents no unusual features. The sinus returning the blood from the branchiae to the heart is unusually large and clearly defined and the pericardial chamber (Plate 12, fig. 15) is more spacious than common, but otherwise the heart, aorta, and sinuses are fashioned upon the usual plan.

The coelomoducts open into the pericardial cavity beside the posterior dorsal commissure by means of well-defined, ciliated mouths, and from this point extend anteriorly, rapidly losing the ciliated coat and assuming the characteristic vacuolated appearance, until they have traversed on half of the length of the main or ventral portion of the organ with which they unite. This main division presents no especially noteworthy peculiarities. The lining epithelium is composed of very clearly defined cells with basal nucleus, and in living material the distal two thirds was evidently filled with some non-staining material that in sections has escaped leaving only the ruptured cell membrane. The openings into the cloaca (Plate 12, fig. 13) are normally placed and are not surrounded by the high columnar cells encountered in several species of this genus.

The nervous system, in its broader details at least, conforms closely to the usual type, and therefore calls for no description beyond that afforded by the figures.

***Chaetoderma lucidum*, sp. nov.**

Fifteen specimens of this species, the majority of them mutilated, were dredged approximately one hundred and forty miles to the eastward of Cape May, New Jersey (Sta. 2588A) at a depth of 479 fathoms. Fully as many more were taken on another occasion slightly to the northeast of this point (Sta. 2212A) at a depth of 428 fathoms, but unfortunately all from this last named locality

had dried prior to coming into my possession and are useless for the study of the internal anatomy. The smaller specimens from both stations agree in being relatively slender, and the larger specimens may retain this characteristic or become relatively thick-set (Plate 9, fig. 12).

The longest specimen measures 25 mm. in length by 0.75 mm. in greatest diameter, while the individual with the greatest diameter, 1.2 mm., is 11.25 mm. long. The color of the specimens from the two stations is strikingly different, though I am of the opinion that this is due to methods of preservation and not to habitat. What appears to be the normal shade in a preserved state is a glistening light yellowish white somewhat darkened by the slaty gray liver shining through the translucent body walls. A reddish yellow or reddish brown incrustation, usually shading into dark brown in the larger individuals, gathers on the spines about the cloacal opening.

Bordering on the union of the pro- and metathorax the spines are in the form of very thin flattened scales without any well-defined keel (Plate 9, fig. 15). In length they range from 0.094 to 0.13 mm., while the width, even in spines of the same length, varies as much as 30 per cent.

The hypodermal layer presents no peculiarities whatever save that the giant cells of Wiren are more abundant than is usual in the region of the pro- and metathorax where the hypodermis shows to the best advantage. In these cells the nucleus is usually basally placed while the cell body contains little save a finely granular coagulum adhering to the cell wall. As the spines in this species have no clearly defined matrix cells in this species the possibility presents itself that these larger hypodermal elements may play a part, but there is nothing to prove conclusively that such is the case. On the other hand they may correspond to the gland cells occurring in *Chaetoderma attenuata*, but the absence of attached fibres penetrating the somatic muscles renders the identification uncertain. The remaining hypodermal elements are generally cubical in form though the cell boundaries, unlike the sharply defined spherical nuclei, are very indistinct.

The buccal plate is broadly shield-shaped with the mouth occupying a deep cleft in the upper two thirds (Plate 10, fig. 11). In sections it is bounded as usual by a heavy cuticular plate (Plate 10, fig. 2) resting upon a modified hypodermal layer in which the cells appear with marked clearness though without any especial peculiarities. In a number of different species of this genus there is a muscle bundle, probably acting as a sphincter oris and appearing clearly in cross sections, and in the present species it is situated immediately internal to a well-defined sensory area that likewise encircles the mouth.

The sense cells are exceedingly long and slender with spindle-shaped nuclei, and internally may be followed into the vicinity of the great nerve bundles passing from the brain into the region of the buccal sensory plate.

Gland cells, attached to the great ganglionic masses applied to the brain or scattered irregularly anterior to the mouth opening, communicate with clearly defined ductules leading to the margins of the buccal plate. Even in moderately stained (Delafield's haematoxylin) material these cells are almost black while the ductules are purple.

The mouth, whose position has been described in a foregoing paragraph, communicates with a canal of moderate size in which the elements, muscular and epithelial, present the customary appearance. Buccal or pharyngeal glands are present in an unusually restricted area. On each side of the mid line a very short distance posterior to the brain they appear as a single lobule (Plate 9, fig. 13) or as two or three closely appressed lobules in which the cells are unusually compact owing to an abundance of a finely granular, moderately staining secretion.

A median ventral ridge immediately anterior to the radula probably represents the subradular organ of other species. The cells are not so distinctly columnar as in *Chaetoderma attenuata* for example, and consequently are not sharply differentiated from the adjoining cells. Nevertheless the absence of folds in the ridge and the fact that it rests upon a typical ganglion with connectives marks it as a definite sense organ.

In several species where the subradular organ and the related nerve supply have been well preserved a lobule of gland cells attaches to the ventral side of the digestive tract on each side of the subradular ganglion. This happens so invariably that it furnishes some evidence for the belief that these organs correspond to the ventral salivary glands in the neomenians, while the scattered yet compact glands attached to the dorsal or even lateral surface represent the dorsal salivary glands. There is at present no more cogent reason than their position for such an opinion, but their constancy indicates that they are structures of long standing.

The radula and its supports and musculature are relatively heavy (Plate 10, fig. 1) but otherwise typical.

Posterior to the radula the alimentary canal narrows rapidly and unites with a highly enlarged section with very thin walls. The outer or proximal boundaries of the lining cells are clearly defined, but the presence of large quantities of a granular secretion in the neighboring lumen suggests that in the act of bringing the animal to the surface or owing to the method of fixation the

distal, glandular products of the cells have become dislodged. Passing through the union of the pro- and metathorax (Plate 9, fig. 18) the epithelial lining becomes thicker. In the anterior end of the metathorax it again grows thin (Plate 9, fig. 16) save in the immediate neighborhood of the dorsal aorta, and where folds appear, especially on the ventral side, the cement substance between the cells assumes the form of minute granules (Plate 10, fig. 7). Intercellular bridges may exist, judging from certain cells, but the state of preservation of the material renders this uncertain.

The liver, gonad, and intestine arise at practically the same level in the posterior end of the metathorax (Plate 10, fig. 4), and are of typical structure and arrangement. The latter statement is likewise true of the entire intestine and of its outlet into the cloacal chamber.

A careful examination has been made of the nervous and circulatory systems, but the results do not call for a description beyond that afforded by the figures. The single specimen sectioned was a male with mature sex products in the gland itself and to a slight extent in the pericardial cavity.

The cloacal chamber may likewise be passed with a few words only. Generally speaking the epithelial lining is composed of low cubical cells that become somewhat more elongated in the neighborhood of the external openings of the coelomoducts. There are, however, no extended patches of columnar epithelium in this region such as occur in *Chaetoderma nitidulum* for example. Each branchia is provided with 11–12 plates so far as can be determined from cross sections.

The coelomoducts communicate with the pericardial chamber by clearly defined ciliated openings in the customary position beside the strong dorsal commissure. Extending anteriorly each canal rapidly loses its ciliated coat, assumes the characteristic glandular appearance and extends anteriorly about one third the entire length of the ventral section with which it then unites. The ventral division is provided with comparatively simple walls, the greatest outpouching occurring at the level of the pericardial openings. The external pores (Plate 10, fig. 3) are located in the usual position in the cloacal cavity.

***Chaetoderma bacillum*, sp. nov.**

Three specimens (one mutilated) of this species were dredged in 906 fathoms in the neighborhood of 200 miles southeast of Cape Cod, Massachusetts (Sta. 2076A). All were silvery gray in color with a slight tinge of buff due to the underlying somatic musculature, and are further characterized by a bright

brick-red incrustation restricted to the spines surrounding the cloacal opening. The two perfect individuals measure 11 mm. and 17 mm. respectively in length by 0.9 mm. and 1.07 mm. in greatest diameter; the mutilated specimen was approximately 13 mm. in length by 1.2 mm. greatest diameter.

The spines are of the customary spearhead-type (Plate 11, fig. 4), with moderate keels, and in the immediate neighborhood of the junction of the pro- and metathorax range from 0.11 mm. to 0.16 mm. in length. In this same region, at least, the hypodermal layer is clearly one cell thick, and generally speaking is composed of cells with clearly defined nuclei but invisible cell boundaries (Plate 10, fig. 13). Among these are nuclei of the same general appearance, but of twice the bulk, that are in contact with, and appear to belong to, spherical or spheroid cavities containing in a preserved state a very small quantity of a finely granular coagulum. What these spaces are it is impossible to state definitely. They may contain calcareous salts in life or, as in several other species, notably *Chaetoderma attenuata*, they may be gland cells. At the base of each is a disc-like darkly staining body, presenting the appearance of a nucleus though this is not conclusive.

Delicate fibres traverse the underlying muscle layer at frequent intervals, and come in contact with the hypodermal layer and at several points appear to pass between the cells and then become lost to view. The nature of these fibres has not been determined. They react somewhat as connective tissue elsewhere in the body, and it may be mentioned are distributed to all of the hypodermal elements alike.

The buccal plate is partially exposed in one specimen only (Plate 11, fig. 6), and appears to resemble a shield in form with the mouth holding a central position. In sections the shield consists of the usual thick cuticular plate resting upon cells of several different types, judging by their form and arrangement. Numerous muscle and large sized nerve fibres pass into the neighborhood of the epithelial cells, but the absence of distinct cell boundaries renders it impossible to determine their exact relations. Darkly staining masses, probably cells though their details are aggravatingly difficult to determine, are attached to the precerebral masses of ganglion cells, and from them delicate ductules make their way to the margins of the buccal plate. In some instances they open through the cuticular plate; in other cases they pass to the outside of its borders.

The mouth opens into a tubular canal without any particularly characteristic features. The lining epithelium, consisting of columnar epithelium

fashioned into a few rather ill-defined folds, is surrounded by the customary muscle sheath in which a relatively few gland cells find lodgement. These last named elements are arranged in small lobules, and the component cells are occasionally charged with considerable quantities of a darkly staining secretion, though this is much more often greatly limited in quantity.

Immediately anterior to the radula a prominent fold appears in the mid ventral line of the digestive tract that is probably a subradular organ. The cells, unlike those elsewhere in the neighborhood, are sharply defined externally and are separated here and there by ductules from two masses of gland cells situated immediately ventral to the ridge in question. That the organ is sensory is evidenced by the fact that it rests upon a ganglion resembling in every important respect the one found in *Chaetoderma attenuata* for example.

The radula (Plate 10, fig. 9) comprises the single tooth, relatively heavy in this species, and the wing-like supports together with matrix cells and muscular attachments that follow closely the arrangement of these organs in other species of the genus.

Posterior to the radula the digestive canal narrows rapidly, becomes circular in outline and after a brief course posteriorly unites with a more expanded portion, probably the commencement of the endodermal section. This enlarged division rapidly develops a variable number of small longitudinal folds — from 18 to 25 — that as the gut gradually narrows upon approaching the metathorax (Plate 10, fig. 12), become correspondingly reduced, finally disappearing altogether. The cells throughout are clearly defined elements with spherical nuclei, and especially on the dorsal side beneath the aorta are distinctly glandular. This state of affairs continues for at least 1.5 mm. into the metathorax. Beyond this point sections were not made of the central portion of the body.

In the posterior end of the animal the intestine, somewhat larger in cross section than common, maintains the usual relations and opens into the cloaca. Its cells, in favorable situations, appear to be more cubical than those of the anterior end of the mid-gut, and present a denser appearance owing to a finely granular secretion they enclose. Diatoms and other substances, organic and inorganic, are present in abundance.

The circulatory system is typical in all essential particulars. The heart (Plate 10, fig. 14) is distinctly more muscular than the average, and the dorsal aorta is not only larger than usual but it is lined with an endothelium uncommonly distinct especially in the anterior end of the body. Beyond this point no other distinctive features have been recognized.

The openings of the coelomoducts into the pericardium occur slightly behind the level of the posterior dorsal commissure. From this point the dorsal section of each of the ducts extends anteriorly and unites with the mid section of the main portion of the organ. This main, glandular or ventral section is characterized by great simplicity. Faint lobes occur in its walls accentuated by a very few internal septa.

The nervous system is normal in all of its essential features.

Chaetoderma squamosum, sp. nov.

A single specimen (Plate 11, fig. 5) of this species was dredged at a depth of 1,234 fathoms (Sta. 2534A) about 200 miles southeast of Cape Cod, Massachusetts. The total length of the body was 25.7 mm. with a width of 1.3 mm. in the prothorax and of 1.2 mm. and 1.7 mm. through the metathorax and abdomen respectively. The color is grayish white due in part to a grayish colored incrustation particularly over the pro- and metathorax and to the lead colored liver partially visible through the translucent body wall and over lying spicules. The buccal sensory plate, roughly elliptical in outline, is somewhat concealed in the semicircular groove; it is apparent, however, that the mouth opening is comparatively small and is entirely surrounded by the plate.

In the neighborhood of the junction of the pro- and metathorax the spines (Plate 11, fig. 9) measure from 0.11 to 0.19 mm., and are further characterized by unusual thinness and the absence of a sharply defined keel. The hypodermis (Plate 13, fig. 7) lacks any distinguishing features. In many places, especially in the anterior end of the body, the nuclei are arranged in two or three layers although the cells to which they belong may actually constitute a single layer. Occasionally the more external nuclei are spindle-shaped, but it is not certain that this characteristic is correlated with any especial function. The nuclei of the spicule-matrix cells are conspicuous objects, nearly twice the size of the ordinary hypodermal nuclei, and are further distinguished by staining a lighter shade.

The buccal plate comprises a thick, external cuticular plate secreted by the underlying hypodermis whose cell boundaries are very difficult to determine. For this reason it is impossible in the present instance to accurately relate these elements to the numerous nerve and muscle fibres and to the ductules of deep seated gland cells. Generally speaking the hypodermal cells are relatively slender, often unusually high in the vicinity of the mouth and at various places muscle cells appear to pass between them to attach to the cuticular plate, while nerve fibres have been undoubtedly seen to attach to the bases of a few cells with spindle-shaped subcentral nuclei. The ductules perforating

the plate, or opening adjacent to it, are usually closely associated with nerve fibres originating in the precerebral ganglia attached to the brain; but they have not been definitely traced to any special set of cells. Several groups of gland cells, of shrunken appearance probably owing to reagents, are imbedded in the wall of the digestive tube in the neighborhood of the mouth. These may be connected with the ductules in question, but on the other hand there are signs that they are in reality buccal glands opening by ill-defined passages into the digestive tract.

In common with other members of the genus, this species possesses a digestive tract comparatively simple in its structural details. The mouth opens into a well-defined buccal tube of average size and with slightly folded walls in which the lining epithelium consists of slender cells possibly ciliated and without very distinct cell boundaries. Immediately anterior to the peg-like tooth the ventral wall becomes modified to form a well-defined patch of slender, ciliated cells — the subradular organ, judging by position and innervation. Here and there, especially in the ventral half of the tract, gland cells are imbedded in the muscular walls, and in some instances at least open into the digestive tract by intercellular ductules. These glands become relatively abundant in the neighborhood of the radula where they chiefly open on prominent folds of the lateral walls of the gut.

The radula (Plate 11, fig. 10) is, as usual, a slender conical structure 0.4 mm. in length, and in its relations, muscular attachments, and matrix cells conforms closely to other species of the genus.

A very short distance posterior to the radula the digestive canal narrows rapidly, becoming elliptical in cross section, whereupon it almost immediately unites with a dilated portion whose walls have been largely stripped of their lining epithelium due apparently to the reduction of pressure upon being brought to the surface. Where it remains the cells agree in being relatively large columnar elements in which the centrally placed nuclei are unusually conspicuous. A darkly staining secretion covers their free surface, but its origin is uncertain, though it may have been elaborated by these cells as they generally show traces of glandular activity. This dilated section of the canal narrows considerably in the posterior end of the prothorax (Plate 11, fig. 8), and as an almost perfectly circular tube extends into the metathorax where it unites in characteristic fashion with the stomach and liver. In the abdomen a mass of diatoms, sponge spicules, and inorganic debris prevented sectioning; in the cloacal regions the position of the gut was typical.

The coelomoducts are comparatively simple structures, holding the usual

position and presenting the customary appearance. Beyond this statement there is little to be added that will aid in diagnosing the species. From its opening into the pericardial cavity each duct, slender in outline pursues a course anteriorly and at the same time assumes a position dorsal to the main or ventral portion of the duct. In this situation, considerably enlarged and with three or four slight folds springing from its inner surface, it extends anteriorly for a considerable distance and becomes continuous with the ventral section. This last named division, relatively large in diameter and likewise supplied with a few folds, extends posteriorly until it has traversed approximately one third the length of the cloacal chamber into which it then opens by a conspicuous pore.

As in several other species of this genus the walls of the cloacal cavity are modified to form a well-defined area surrounding the external openings of the coelomoducts. The component cells comprise slender supporting cells and elongated gland cells sharply defined from the cubical elements that at other points line the chamber.

The nervous and circulatory systems were studied in detail, but no especially noteworthy features were encountered.

Neomenia verrilli, sp. nov.

A single specimen of this species occurs in the present collection, bearing the label "Gulf of St. Lawrence, 313 f'ms. J. F. Whiteaves, 1872." The animal has been decalcified and cut open along the mid dorsal line, an operation that has destroyed some of the organs though their general plan is still discernible. The body is thick-set (Plate 3, fig. 6), bean-like in form and measures approximately 25 mm. in length by 8 mm. greatest diameter. The color in a preserved state is light yellow.

The work of decalcification is complete, not a sign of a spicule being evident, yet it is certain that, as in other species of Neomeniidac, one layer of spines was present originally. While the papillae differ in detail among themselves, these variations appear to be due to growth and possibly to some extent to fixation. Little if any pigment is present in the component cells, and no clearly defined nerve supply has been traced to them. It may be added that these organs are comparatively numerous (Plate 3, fig. 8). The remaining hypodermal cells are comparatively small, without clearly defined boundaries and are devoid of features of special interest. No dorsal keel exists.

A well-defined spiculose, cuticular bridge separates the atrial cavity from

the external opening of the anterior pedal gland. Anteriorly this last named space appears as a narrow slit, when viewed from the mid line, but in cross section it is seen to extend far outward on each side and to possess plain though highly glandular walls. About midway its dorsal wall loses its glandular character and develops numerous folds, large and small, which more posteriorly decrease to seven or eight. In the middle of the body the foot has been cut away, but in the posterior third it reappears with this reduced number of folds. Whether this condition continues to the cloacal chamber cannot be determined owing to slight mutilations.

As noted previously the anterior, plain-walled section of the anterior pedal gland outlet is composed of highly glandular cells whose secretion, after treatment with Delafield's haematoxylin, stains a uniform lavender tint. With the appearance of the folds on its dorsal surface the component cells lose their glandular character, and the deeper seated cells, pyriform in shape and opening by delicate ductules through the folds, stain intensely and probably represent the anterior pedal gland of other neomenians. Posterior to the anterior pedal gland outlet these last named glandular elements decrease in size and number and shade into the posterior pedal gland.

The extremities of the body presented almost identically the same appearance, and it was only from the study of sections that the atrial opening was definitely located. The cirrose cavity into which it leads is relatively small, and is almost completely separated into two subdivisions crowded on each side of the body against the body wall (Plate 4, fig. 7). While there are no clearly differentiated sensory ridges bounding the cirrose area, the entire atrial cavity, with the exception of the cirri themselves, is lined with an epithelium composed of high and slender cells similar to those composing the ridges in other species. Appearances indicate that these cells are sensory in character, but the absence of undoubted nerves renders the identification uncertain. Along the inner boundary of the cirrose area is an unusually high fold that like a curtain shuts off to a large extent these lateral cavities from the median space, which may represent the buccal cavity. If this fold represents the inner atrial ridge of other *Solenogastres* its cells, low in form and non-ciliated, give no indication of possessing any sensory function.

At the commencement of the buccal or pharyngeal cavity, a great fold, seamed with numerous minor corrugations, springs from the dorsal side, and in the first part of its course almost fills the cavity. More posteriorly it becomes subdivided into three or four lesser folds, that, with others which have arisen

on the lateral and ventral surfaces of the pharynx, extend longitudinally to a point probably corresponding to the posterior end of the pharyngeal tube where they terminate as abruptly as they began (Plate 3, fig. 4). All of these folds are deeply furrowed with secondary ridges, and are supported by an abundance of muscle and connective tissue, which likewise give support to a large number of gland cells. These last named elements appear to be grouped in the form of slender lobules, but the protoplasm of which they are composed stains but faintly, and their relations with the overlying epithelium are obscure. At several points what appear to be ductules are evident, and a darkly staining secretion on the exposed surface of the pharyngeal epithelium indicates that the products from these cells escape as usual by intercellular channels.

As noted in the foregoing paragraph the large pharyngeal folds end abruptly posteriorly; and immediately behind them a large circular fold arises composed of muscle and connective tissue penetrated by blood sinuses. This fold appears to be capable of a certain amount of protrusion, but owing to the lack of well-defined protractors and retractors its movement is probably limited. The lining epithelium is composed of high, slender cells charged distally with a granular secretion not encountered elsewhere in the digestive tract. Distinct ventral salivary glands are absent, and it is possible that these cells are homologous or at all events that they perform a similar function.

No radula is present.

Beyond this circular fold the stomach-intestine appears with walls fashioned into numerous longitudinal folds lined internally with digestive cells without distinct boundaries and densely packed with innumerable granules. Along the mid-ventral line the cells of this character blend insensibly with others, almost cubical in form, and non-glandular, that anteriorly form a narrow trough-like tract which nearer the middle of the body develops folds and in this condition extends to the region of the seminal receptacles. Here the intestine narrows to pass between the limbs of the coelomoducts, and this non-glandular portion of the gut gradually extends toward the dorsal side until at the anal opening it comprises fully half of the digestive tube. The mutilation of the specimen renders it impossible to state with certainty, but it appears that the dorsal glandular tract does not disappear until the cloacal chamber is reached.

The cloacal cavity is a spacious chamber, and as in other species of the genus its walls are provided with extensive branchial folds (Plate 4, fig. 5), numbering apparently between fifteen and twenty pairs. These in turn are often supplied with many secondary folds, the appearance in cross section reminding one strongly of *ctenidia*.

Between the bases of these folds and the somatic musculature are large numbers of gland cells separated into small lobules by connective-tissue septa between which blood sinuses make their way. No traces of ductules are apparent though there are evidences here and there, possibly a *post mortem* effect, that some of the cells have released their hold and are free in the blood stream, while others, attached by very slender stalks, appear to be in process of liberation. In a general way these elements remind one of the concreted cells as described by Brock (1883), but there is no definite evidence that they are homologous or that they function similarly.

The circulatory system has suffered to a greater extent from the mutilation of the specimen than any other set of organs, but so far as determined it conforms closely to the neomenian type. The pericardial cavity is of moderate size only, and the ventral displacement indicated in the reconstruction (Plate 3, fig. 1), may be an abnormal state of affairs. As indicated there is a shallow pouch-like expansion of the forward wall in the neighborhood of the renopericardial openings, but with the exception of a somewhat thicker, slightly corrugated wall there are no indications that it may play any especial function.

The heart is a two-chambered organ, the blood from the branchiae and the dorsal part of the posterior end of the body entering the hindmost section. There are indications of a valve guarding the union of the two divisions. The clearly defined dorsal aorta, holding the usual position and supplying the customary organs, makes its way to the head cavity, and there communicates with an extensive system of spaces which in turn soon combine to form the median ventral sinus and that of the general visceral cavity. In the posterior end of the body, about the level of the anterior end of the shell gland, the first named of these canals rapidly diminishes in size, while the other communicates with spaces leading into the branchiae and beyond them into the heart.

The nervous system is more than usually well-defined, and for this reason more than ordinary care has been taken to determine the position of the various ganglia and their more important branches. The brain occupies the usual position above the atrial cavity, and with the exception of its comparatively small size presents no especially noteworthy features. As usual it originates on its anterior face several nerves that are distributed to the atrium and the adjacent body wall; and laterally it gives rise to the connectives passing to the labiobuccal, lateral, and ventral ganglia. The last named connectives like the brain, are of exceptionally small calibre, and lying loosely in the visceral cavity may be traced to the region of the outlet of the anterior pedal gland where they unite with the ventral ganglia. Close to the point of union the ganglia

are strongly enlarged, and are united by two commissures of considerably larger size than those in a more posterior position.

With the exception of the most anterior, the connectives uniting the lateral and ventral ganglia are spaced at fairly definite intervals. The exception arises on each side from what appears to be the connective to the ventral ganglion since no nerve cells occur in its vicinity, and on the other hand it unites with the anterior swollen extremity of the lateral cords. The last named enlargement gives rise to two strong branches of which the smaller, directed anteriorly, makes its way into the vicinity of the bases of the cirri. The other makes its way ventrally and is distributed in part to the somatic muscles, while a comparatively large nerve extends between the lobules of the anterior pedal gland where it becomes lost to view. Another nerve destined to the same organ arises from the lateral cords about midway between the first and second latero-ventral connectives.

As usual nerves spring from the dorsal side of the lateral ganglia, and though clearly defined and of relatively large size none have been traced as far as the mid-dorsal line. They branch repeatedly over the internal face of the somatic muscles which they probably innervate together with the overlying hypodermis.

The labiobuccal connectives are so closely associated with the lateral for a short distance beyond the brain that though they are fairly distinct they nevertheless occupy the same sheath. Beyond this point they may be followed with unusual clearness, and owing to this fact more than ordinary care has been exercised in determining the relation of the principal elements. Loosely attached to the muscular coat of the digestive tract each connective extends posteriorly to the labiobuccal ganglion placed about opposite the posterior end of the outlet of the anterior pedal gland. At approximately two thirds of its length from the brain two or three branches are developed of which the largest, crossing the dorsal surface of the pharynx, forms a commissure. The others, imbedded in the muscular pharyngeal walls, have been followed to a greater or less extent until their subdivisions become so small in cross sections that they disappear from view. At many points minute nerves appear in the pharyngeal wall, and give the impression that they are parts of an extensive plexus such as is known to ensheath the digestive tract in several other molluscs. Other nerves of this same character occur at a short distance anterior to the labiobuccal ganglia.

Immediately in front of the ganglia a simple, ventral commissure occurs.

A few small nerves arise from it, but soon become lost to sight in the ventral pharyngeal musculature. The labiobuccal ganglia are sharply defined spherical structures, and each is connected by a dorsal and ventral commissure. There are thus two dorsal and two ventral commissures, but no signs whatever of a subradular complex. This is not surprising as a radula is lacking completely, and a subradular organ, if such exists, is far from being a sharply differentiated structure.

The nervous system in the posterior end of the animal has been partially destroyed so that only the broader features have been worked out. Its general configuration, however, is essentially the same as in *Drepanomenia vampyrella*. The pedal cords continue to a point about opposite the middle of the cloacal coccum or vagina (Wiren) where they bend abruptly, and coursing dorsally and posteriorly unite with the lateral cords slightly ventral to the openings of the coelomoducts into the pericardium. From this point of union, on one side, a heavy nerve, doubtless the dorsal commissure, extends for a considerable distance toward the mid line. The commissures uniting the pedal cords appear to be more numerous than the latero-pedal connectives, but beyond this fact no especially interesting features have been observed.

As usual the animal is monoecious, and in this instance is sexually mature, the swollen gland extending from the pharyngeal region to the pericardium being distended with sex products in all stages of development. Anteriorly the ovo-testis contains sperms only, but a very short distance behind the forward tip of the organ ova appear attached as usual to the inner faces of the tubes. The canals leading into the pericardium are comparatively short, though of more than average diameter, and are richly ciliated throughout. As is more fully described in the section on the circulation, the pericardium is provided on each side of the body with two relatively wide diverticula with which the coelomoducts connect. The reno-pericardial openings are unusually wide and conspicuous, and are further distinguished by being surrounded by cells of greater height than is encountered elsewhere in the pericardial wall and by bearing a ciliated coat.

The upper section of each coelomoduct, pursuing its way anteriorly to the region of the seminal receptacle, is of more than ordinary length and is fashioned into a number of short turns (Plate 3, fig. 4) that give it a somewhat complicated appearance in cross section. Throughout its entire extent each canal is provided with a dozen or more high, longitudinal ridges supported by muscle and connective-tissue fibres penetrated in many instances by blood sinuses. The component epithelial cells are relatively slender, of

moderate height and in addition to containing small amounts of some finely granular substance support a well-defined ciliated coat.

At the junction of the dorsal and ventral divisions of the coelomoducts on each side is a large vesicular appendage (re) that probably functions as a seminal receptacle since each contains a very few spermatozoa together with a small amount of some glandular secretion. The walls of the neck-like duct are similar to those of the dorsal limb of the coelomoduct, and are heavily ciliated, as are the cells of the receptacle adjacent to it. On the other hand the walls of the expanded portion comprise cells of two types, goblet-shaped glandular elements with basal or subcentral nuclei, and exceedingly slender supporting cells. The secretion of the first named class is restricted to the distal half of the cell, and from its homogeneous appearance and seemingly viscous character probably exists in the form of a fluid in living material.

The ventral limbs of the coelomoducts hold the customary relation to the other organs in the posterior end of the body, and are not only of relatively small diameter but the walls are comparatively thin. From the quantities of secretion imbedded in the walls it appears probable that this is the usual state of affairs. The epithelial lining is thrown into folds of varying sizes each supported usually by fibres sent in from the sheath surrounding the organ. The cells are high, slender elements with the distal portion containing groups of small granules staining moderately with Delafield's haematoxylin. This state of affairs continues to the median, undivided section where the cells become more nearly cubical especially in the neighborhood of the opening into the cloacal chamber. The external reproductive pore does not communicate directly with the general cloacal cavity, but with a compartment of it that in turn gives rise to the diverticula responsible for the development of the penial spines. Ventrally this same space leads into a heavy tubular outgrowth termed by Wiren (1892) the vagina or copulation organ.

The so-called vagina (co) is a diverticulum of the anterior cloacal wall reinforced with a heavy muscular sheath. The muscular elements comprise three classes, an innermost, heavy circular layer external to which is a thin covering of longitudinal fibres, while here and there small, radiating bundles extend through these layers from the neighborhood of the inner epithelial lining. The internal bounding membrane consists of slender, ciliated cells, apparently slightly glandular, produced into numerous small folds. Along the mid-ventral line the muscular sheaths are pushed inward, thus producing a species of typhlosole that continues throughout the greater part of the organ.

Distally the vagina opens into a pair of relatively large sac-like organs

symmetrically placed on each side of the mid line. From sections, which pass longitudinally through these structures, it is very difficult to gain a clear idea of their character, and, as will be seen, it is equally trying to ascribe to them a definite function. The epithelial lining appears to be fashioned into a large number of heavy folds (Plate 3, fig. 3), and occasionally where the walls are bare they appear golden yellow in color after treatment with haematoxylin. This seemingly is due to large quantities of secretion, though even with high magnification cell boundaries and nuclei are invisible. Generally speaking the lining epithelium affords attachment for myriads of spermatozoa, which, with great regularity of arrangement, seem to be imbedded in the cells themselves, while the tails extend outwardly and together with the above mentioned secretion practically fill the lumen of the organ. Even in portions of the vagina and the expansions of the cloacal wall, into which the penial spines emerge, sperms find attachment to the lining epithelium though their numbers per unit area are considerably less than in the vesicles themselves. It may be mentioned that the golden yellow secretion occurs at intervals throughout the vagina and lateral to it, having apparently passed into these locations from the sac-like expansions or vesicles.

Regularity of arrangement of spermatozoa within a vesicle is usually considered to be an indication that the organ in question functions as a seminal receptacle, while the reverse condition indicates that the structure plays the rôle of a seminal vesicle. If such a line of argument be followed in the present instance then these pouches are seminal receptacles. It is a very unusual thing, unique in fact, to find organs such as these in such a situation, and it is the more difficult to look upon them as receptacles since a pair of these last named organs occurs in the usual position at the junction of the dorsal and ventral limbs of the coelomoducts. It is possible that they function as such temporarily, and that the sperms take up their final position in the usual receptacles, but nothing short of a series of specimens in different stages of sexual maturity will indicate the true solution of the problem.

Wiren (1892) has described a vesicular attachment, filled with sperms, of the dorsal limbs of the coelomoducts in the neighborhood of the pericardial openings in *Neomenia carinata*. In sections they hold the same general position that the sperm sacs do in the present species, but in our specimen the dorsal limbs are unmutilated, and a careful examination of them throughout their entire length fails to disclose any spermatozoa, much less any noticeable enlargement.

Each penial spicule sheath and the included spine are of unusual length and girth, and with the accompanying muscles form a very conspicuous element of the accessory reproductive apparatus. In addition to these elements there exists a trough-like guide or groove (Plate 4, fig. 8) in which the spicule rests. As in the case of the spine this guide appears to be cuticular in character, but whether in life this serves as a matrix for calcium salts it is impossible to state at present. Both of the structures are secreted by numerous slender cells, clear and well-defined at the distal extremity of the sheath, but growing indistinguishable near the free opposite end.

The external sheath is composed largely of connective tissue to which the retractor and protractor muscles are attached. The first named are of larger size and are united with the sheath in the neighborhood of its distal extremity. On the other hand they become inserted chiefly in the cuticular trough though small slips extend to the spine that thus is possessed of a certain amount of independent action. The protractors attaching to the spine are comparatively thin and delicate, and, so far as may be judged from sections, are attached both to the grooved guide and to the sheath. Another protractor, of much larger size, is inserted in the grooved plate near its outer end, and extending in a postero-ventral direction fuses with the somatic musculature lateral to the posterior termination of the foot.

In addition to these elements the spicular apparatus comprises a pair of highly developed glands (pgl) that in the present instance are fully as large as the shell gland. Each of these is placed somewhat above and to the inside of the ventral limbs of the coelomoducts or shell gland (Plate 4, fig. 1), and presents the appearance of an inflated sac ellipsoid in form. Internally well-defined septa spring from the walls, and in the anterior end of the organ these become so united that they form a number of diverticula communicating with the main cavity of the gland. The cells of the epithelial lining are more or less goblet-like in shape, and distally contain vacuoles in which are occasional globules of some secretion.

In the neighborhood of the free extremity of the retracted spine a duct opens into the surrounding space, and on the other hand passes laterally then dorsally and toward the mid line to enter the mass of connective tissue ventral to the shell gland. In this position, close to the gland just described, it becomes lost to view owing to the mutilation of the specimen. Two possibilities present themselves; either it opens into the shell gland or into this large, overlying gland. The former course appears unlikely, especially in view of the fact

that in *Neomenia carinata* Wiren (1892) has described a large accessory penial gland whose relations bear a close resemblance to the state of affairs in the present case.

In conclusion it may be added that the members of the genus *Neomenia* can scarcely be considered primitive. The complexity of the reproductive system especially, with its penial spines and glands, seminal vesicles, and receptacles, appears to indicate that the genus stands in about the same relation to the primitive mollusc that the pulmonates do to the prosobranchs.

***Proneomenia acuminata* WIREN.**

One specimen of this species was dredged in the Straits of Florida (Sta. 5 Be) at a depth of 152–229 fathoms; a second was taken south of Martha's Vineyard, Mass. (St. 893 Fk) at a depth of 372 fathoms; while a third came from practically the same location (Sta. 2547 A) at a depth of 390 fathoms. The first is somewhat distorted, and in a normal state probably measured not far from 20 mm. in length by 1.7 mm. in thickness: the second is 23 mm. long by 1.8 mm. thick; the third measures 30 mm. in length by 1.7 mm. in diameter. The anterior end is bluntly rounded (Plate 5, fig. 3), while the posterior extremity terminates in a rounded point, and owing to the large size of the cloacal opening it is probable that in life its borders can be widely expanded as in the case of *Ichthyomenia ichthyodes*.

The atrial opening, surrounded by rounded, prominent lips, is distinctly separated from the ventral groove whose anterior excavation, the outlet of the anterior pedal gland, is invisible externally though in decalcified material it shows faintly through the translucent cuticle. While the outline of the outlet is somewhat irregular in form it consists, generally speaking, of hemispherical diverticula extending laterally a short distance from the ventral groove.

The anterior pedal gland is a voluminous organ occupying most of the visceral cavity between the region of the radula and the outlet of the dorsal salivary gland. Although the cells are of varying size, owing to age or the amount of secretion they contain, all agree in being more or less pyriform with an irregular somewhat varicose ductule leading to the exterior of the body. The secretion itself is invariably finely granular, staining intensely in Delafield's haematoxylin, and usually fills the cell. As is the case generally with the *Neomeniidae* the ductules open by intercellular channels into the anterior end of the ventral furrow.

The posterior pedal gland is directly continuous with the anterior from which it differs in no essential particular, save in the smaller size of the cells and their lesser number. The ductules lead to the median fold, or rudimentary foot, and in addition are distributed to the epithelium of the ventral groove generally as far as the spiculose cuticle. With the posterior termination of the foot in the neighborhood of the external reproductive pore, these cells disappear, but close behind the gonoduct exit the wall of the cloaca is supplied with a scattering band of cells of the same character opening along the border of the spiculose cuticle.

The cuticle is of moderate thickness only and the hypodermis is exceptionally thin and its cells difficult to interpret. The spicules, with which the cuticle is crowded, are of the customary proneomenian type, slender, slightly curved needle-shaped structures (Plate 5, fig. 4) arranged in approximately seven layers. Radially directed spines appear to be lacking excepting in the region of the ventral groove.

The papillae (Plate 5, fig. 6) appear in life to have been filled with a highly fluid substance that after treatment with reagents largely disappears, leaving the few component cells in a much shriveled condition. In the expanded portion five to seven nuclei are usually visible; none appear in the stalk.

As noted previously the hypodermis is a very thin sheet, and the component cells are very inconspicuous. The spicule-matrix elements on the other hand are relatively distinct, and maintain essentially the same relations as in *Proneomenia hawaiiensis* for example. The cells retain their attachment to the spine until the latter has travelled halfway to the surface of the body, and in some cases they retain their connection for a longer period.

The position of the dorso-terminal sense organ was discernible in surface view, owing to the presence of numerous, small overarching spines though the cavity itself was not visible. In sections it presents the appearance of a hemispherical depression composed of very slender cells resting upon the somatic musculature. A unique feature appears in the form of a comparatively large number of gland cells filled with a darkly staining secretion, located about the rim of the pit adjoining the spiculose cuticle. In some instances the cells are in the general hypodermal layer; in other cases they are in the underlying tissue, but in any case they open through intercellular spaces about the margin of the depression.

There are strong reasons for the belief, first expressed by Thiele, that the anterior enlargement of the digestive tract, with its ciliated ridges and finger-

shaped cirri, is in reality a modified snout homologous with that in the Chitons, and perhaps with the sensory shield in the Chaetodermatidae. On such an assumption the true mouth is deeply seated, and in the present case is in the neighborhood of the outlet of the dorsal salivary gland.

In the specimen in hand the atrial opening, subterminal in position is a relatively long narrow slit leading into a spacious chamber, the atrial cavity, whose limits are fairly well-defined by two prominent horseshoe-shaped ridges, which fuse posteriorly (Plate 5, fig. 1). The first of these, the outermost and continuous across the mid line, courses parallel to the borders of the outer opening, and is bounded externally by slender cells bearing a well-defined coat of cilia. Internally it is supported by an abundance of connective tissue and is penetrated by a blood sinus distended by blood corpuscles. It thus appears, as has been suggested, that these organs may play a part in the process of respiration, but the nature of the overlying epithelium and the presence of nerve fibres beneath it indicates also that it is a sense organ though its office is unknown.

As in *Proneomenia hawaiiensis* and some other neomenians, this external atrial ridge is bounded on its outer side by a lower prominence (Plate 5, fig. 1) whose slender cells are fully twice as high and are evidently sensory. In this species fibres may be traced into its neighborhood, but it is not so evident that they are sensory as in a few other species. In *P. hawaiiensis* a cord-like group of ganglion cells is situated in close proximity to the overlying ridge, which it supplies with numerous delicate fibres, and in the opposite direction is united at fairly frequent intervals with some of the ganglia located about the bases of the cirri. There thus appears to be little doubt that in such cases we are dealing with a definite sense organ, and it is probable that in *Proneomenia acuminata* the same is true.

Throughout its entire extent this external sensory ridge contains a small number of gland cells, whose slightly vacuolated secretion stains intensely in haematoxylin. In the posterior third of its course additional cells of the same character appear in the outlying hypodermis beneath the spiculate investment, and in this position they continue to the posterior border of the atrial cavity.

The inner atrial ridge, in form and structure and perhaps in function, is the counterpart of the external one (Plate 5, fig. 1).

In the area circumscribed by these prominences the cirrose area is located, and is characterized in the present instance by numerous slender diverticula of the atrial wall. These arise singly, and are further distinguished by multi-

tudes of slender, lightly staining cells containing small quantities of yellowish pigment. The contained cavity is extremely slender, preventing the entrance of blood corpuscles but allowing the entrance of slender fibres from the underlying tissue. In certain species these fibres appear to be in part branches of nerves and such may be the case here, but the contorted appearance of these organs leads to the belief that contained muscle fibres are, at least in part, responsible for their condition.

Immediately behind the union of the atrial ridges the wall of the digestive tract is smooth, but rapidly develops folds, as the pharynx is approached, of irregular appearance and bounded by the cubical cells characteristic of the pharyngeal epithelium generally. The accompanying figure (Plate 5, fig. 1) represents approximately the existing state of affairs, but the folds though generally longitudinal are somewhat diagrammatically shown.

In this species the dorsal salivary gland (Plate 4, fig. 11, Plate 5, fig. 1) is a marked feature, owing to its size and compactness. It comprises numerous globular or pear-shaped lobules of various sizes bounded by a connective-tissue sheath, and in every instance these are without central cavities. The component cells are pyriform, and their ductules open by intercellular channels in the epithelium of the prominent diverticulum on the dorsal wall of the pharynx. Vacuoles are abundant in their cytoplasm, and in life they are doubtless filled with a secretion that in preserved material stains very faintly in haematoxylin.

From the outlet of the dorsal salivary gland to the forward end of the radula the pharynx is approximately circular in outline, and is reinforced by a layer of circular muscles and more externally by a longitudinal set. Radiating bundles, acting as dilators, pass from this muscle sheath to the body wall.

The ventral salivary glands are tubular, paired organs about 3 mm. in length, situated throughout the greater part of their course on the ventral side of the body between the stomach-intestine and the body wall. The component cells, all bordering on the narrow centrally placed lumen (Plate 5, fig. 2), are without definite cell boundaries, and the secretion they elaborate occupies numerous vacuoles in the cytoplasm except in the immediate vicinity of the basal or subcentral nuclei. In close proximity to its outlet into the pharynx this glandular portion passes abruptly into a much more slender, non-glandular duct leading to the opening at the side of the exposed portion of the radula. In this non-glandular section the lumen is eccentrically placed, the ventral cells being three or four times longer than those of the dorsal side.

The radula is a well-defined structure, normally placed, and is of the poly-

stichous type. The teeth (Plate 4, fig. 9) are comparatively small and delicate, and as far as may be judged from cross sections number approximately twenty-eight in each transverse row of which there appear to be about forty-five, though this last estimate is difficult to prove definitely. The radular supports lack the vesicular structures found in several other species of neomenians, and consist entirely of a compact mass of muscle and connective-tissue fibres far too intricate to define accurately from the study of sections alone. It may be said, however, that close to the posterior end of the radula fibres pass to the overlying pharynx or oesophagus, and others, much more powerful, extend from the extreme posterior tip to the overlying radula sheath. In addition to these, numbers of others extend from the radula sheath to the walls of the pharynx. It thus appears that the radula, by reason of its intrinsic muscles, is capable of considerable movement but probably, during the feeding process, the greatest motion is produced by the protrusion and retraction of the pharynx which carries the radula forward and backward.

In *Proneomenia hawaiiensis* two well-defined subradular organs exist innervated by fibres from ganglia, connectives, and commissure essentially the same as in the Chitons for example. In the present specimen two patches of modified cells, of the same character, exist and as they are in close proximity to a pair of small ganglia it is reasonable to believe that here likewise we are dealing with a definite sense organ. The component cells (Plate 4, fig. 10) form knob-like elevations, surrounded by a shallow groove, on each side of the forward border of the radula. Posteriorly they become continuous with the ventral wall of the short, non-glandular ducts from the ventral salivary glands so that the secretion from these organs pours over them in escaping into the pharynx.

In addition to these two modified areas the epithelium, continuous with them across the mid line, is also of unusual height, being fully three times thicker than that bounding the pharynx elsewhere (Plate 4, fig. 10). Its cells appear, though not clearly, to contain small amounts of some faintly staining secretion, but whether this is associated with a special sensory function has not been determined since no definite nerve supply has been detected.

Immediately behind the radula the pharynx unites with the stomach-intestine without any material change in the character of the epithelial lining or the nature of its longitudinal folds. And furthermore the stomach-intestine itself with its glandular lining and regular outpouchings does not differ from the usual neomenian type, though certain features demand a brief description.

The first of these concerns the anterior dorsal coecum, which extends as far forward as the brain. Throughout its entire course it is dorsoventrally compressed, and is totally devoid of pouches though its lining epithelium resembles that of the stomach-intestine. Ventral to its base (Plate 5, figs. 1, 2) is a much smaller, anteriorly directed coecum similar, in the character of its lining cells, muscular sheath and folds, to the pharynx with which it is directly continuous. Finally the pharyngeal epithelium extends along the ventral side of the digestive tract as far as a dorsoventrally compressed ventral coecum whose cells are identical with those of the stomach-intestine. It is thus apparent that the pharynx or oesophagus dilates posteriorly into a funnel-shaped structure and in this form unites with the stomach-intestine.

The stomach-intestine, with its lateral sacculations, dorsal ciliated tract, and lining of digestive cells, presents no especially noteworthy features. As it passes between the limbs of the gonoducts it becomes triangular, then more or less elliptical as it crosses the undivided section and finally as an almost circular canal it opens into the cloaca.

The cloacal chamber is of moderate size only (Plate 5, fig. 5), and its plain or only slightly folded walls exhibit no especial peculiarities though it may be said that the cells forming the lateral walls are heavily ciliated. Undigested material, associated with some darkly staining secretion, fills the cavity with the exception of that held by a parasitic or commensal worm, apparently a rhabdocoele.

The condition of the present specimen indicates that the breeding season was close at hand, as the gonad is greatly distended with sex products and the gonoducts are in a condition of great glandular activity. The reproductive gland, distinctly paired throughout, extends anteriorly as far as the level of the radula, and on the other hand unites, as usual, with the front end of the pericardial cavity. With the extreme forward tip of each division of the gonad the organ is filled laterally with male products, in all stages of development while large numbers of what appear to be nearly mature ova attach to the wall along the mid line.

Posteriorly the conditions are peculiar. The halves of the gland diverge widely until in the region of the pericardium they are separated by a space nearly equal to one third the diameter of the body. This intervening space is spanned dorsoventrally by muscle fibres, and is filled with blood corpuscles and furthermore is directly continuous with the heart so that it is doubtless a greatly expanded aorta. Close to the posterior end of each half of the ovo-

testis a small duct arises from the dorsal side and coursing ventrally to a slight degree it then pursues a direct path (about once again as long as is represented in Plate 5, fig. 5) to the forward end of the pericardium. The lateral walls of these small canals are folded to a slight degree, and the slender cells support a ciliated coat. Toward the mid line the walls are relatively smooth and serve for the attachment of small numbers of spermatozoa that have also made their way into the front end of the pericardium.

Posteriorly the walls of the pericardium are continuous with the coelomoducts that arise as slender tubes with plain walls consisting of cubical, ciliated cells. During the first part of their course each is crowded between the shell gland and the somatic musculature, but after extending upwards of one third the distance to their anterior attachment they shift into the angle between the shell gland and the seminal receptacle and become considerably enlarged. The walls show slight signs of glandular activity and here and there the cells form slight folds. The opening into the shell gland is borne on the summit of a hemispherical papilla, and is further marked by a yellowish secretion (unstained in haematoxylin) that has escaped from the dorsal section and may be traced some distance posteriorly in the lumen of the shell gland.

Each seminal receptacle is an elongated sac, of sinuous outline when viewed dorsally, resting upon the anterior horn of the shell gland. The walls are relatively thick with slight folds here and there and present a dense appearance due apparently to the presence of a finely granular secretion. A very few spermatozoa find attachment to the walls. The union with the shell gland is made by means of a very slender, short tube placed slightly in front of the union of the dorsal and ventral sections of the coelomoduct.

The shell gland, or ventral division of the coelomoduct, is of the usual horseshoe-shape, and as may be seen in the figures is a massive affair. For a distance equal to half the length of the seminal receptacle its epithelial lining is charged with a darkly staining granular secretion that in many places has escaped into the adjacent relatively large lumen. Posterior to this point the nature of the cells changes abruptly for not only do they become of greater height but the secretion, practically unaffected by haematoxylin, acts as though in life it had been of a highly viscous character. This is especially true of the elements of the ventral half of the organ which continue to present this appearance throughout the median, undivided section of the shell gland as far as the point where it narrows to form the small, non-glandular tube communicating with the cloacal chamber. On the other hand the dorsal cells of the median

division of shell gland become charged with a darkly staining, partially granular, secretion which likewise extends to the narrow canal communicating with the cloaca. The terminal section of the coelomoducts is a tube of comparatively small diameter (Plate 5, figs. 5, 8) composed of slender cells fashioned into several inconspicuous folds. Circular muscles form a sheath about it, and radiating bands, probably functioning as dilators, pass from it to the body wall.

In sections it may be seen that the spiculose investment of the animal extends within the body as far as the external reproductive aperture (Plate 5, fig. 5). What probably function as copulatory spicules occur at the sides of the ventral furrow (openings shown in Plate 5, fig. 8) a short distance in front of the posterior end of the foot. These organs present the form of needle-like bodies, so far as can be judged from decalcified specimens, are probably derived from the usual type of spine occurring everywhere in the region of the ventral furrow, and form two groups of from 12-14 on each side of the mid line. Each spine occupies its individual sheath, which extends anteriorly and laterally from the outer opening, and ends blindly where a single matrix cell is located. While no definite muscles appear to attach to these bodies, the region in which they occur, and in fact the entire border of the cloacal chamber, is highly muscular and doubtless can be opened widely, thus bringing these penial spines into an exposed position.

The type-specimens of this species was taken in the "West Indies" at a depth of 540 meters, practically the same as the habitat of the present specimens. Some of Wiren's reconstructions and drawings of various organs appear to be somewhat diagrammatic and do not entirely accord with what exists in the specimens in hand. Accordingly the foregoing detailed description has been arranged with the hope that it may be compared with Wiren's account and the type-specimen.

***Dorymenia peroneopsis*, sp. nov.**

A single, unattached specimen of this species was dredged south of Martha's Vineyard, Massachusetts (Sta. 2715A) at a depth of 1,753 fathoms. The body measuring approximately 25 mm. in length by 2 mm. in greatest thickness, is broadly elliptical in cross section with a slight flattening of the ventral surface. The anterior end is bluntly rounded while the posterior extremity tapers abruptly to a point. From external view no line of separation exists between the atrial opening and the ventral furrow, and sections show that the usual spiculose bridge is lacking. The outlet of the anterior pedal gland is accordingly located

immediately behind the external opening of the atrium, although otherwise it is not especially modified externally. The ventral furrow is continuous with the eloeal chamber. The eloeal opening is relatively large, ventrally placed and is overarched by the posterior pointed end of the body, whose lateral margins may perhaps be separated in life to expose the genital spicula, the appearance of the hinder end of the animal at such times resembling *Ichthyomenia ichthyodes*.

A well-developed dorso-terminal sense organ (Plate 7, fig. 7), visible in sections only, is present about the level of the anterior margin of the eloeal opening. It presents the usual cup-shaped appearance, is adjacent to the median dorsal sinus entering the posterior end of the heart, and is innervated by two nerves springing from the mid section of the suprarectal commissure lying immediately posterior to the pericardium.

The cuticle investing the body is of more than average thickness (0.1 mm.) and is developed by a hypodermal layer whose component cells are not clearly defined and therefore are unfavorable for study. So far as could be determined they comprise three types, columnar elements seemingly responsible for the development of the cuticle, spicule-matrix cells which in early stages are indistinguishable from the foregoing, and those forming the papillae. These last named structures are stubby bodies (Plate 8, fig. 9), resembling an inverted cone composed of highly vacuolated protoplasm in which nuclei are usually visible throughout the entire organ.

The spicules are hollow, needle-like bodies (Plate 8, fig. 2) those of alternate layers crossing the others almost at right angles. In their formation no points of especial interest have appeared. As usual several cells take part in the process, and after functioning appear to shrink back into the hypodermal layer without retaining any visible connection with the spicule. The average length of fully developed spines from the sides of the body about the middle of the animal measure from 0.4 to 0.48 mm.

The anterior pedal gland is an organ of moderate size occupying the major portion of the visceral cavity between the level of the mid section of the atrial cavity and the posterior border of the brain. The component pyriform cells, measuring from 0.017 to 0.0216 mm. in greatest length, are early filled with a stringy, violet colored secretion, after treatment with Delafield's haematoxylin, which becomes finely granular in the later stages of its development. Each cell is continuous, as usual, with a delicate ductule which opens by an inter-cellular channel to the exterior.

The outlet of the anterior pedal gland, when viewed laterally from the mid line, presents the appearance of a fairly long, narrow slit (Plate 7, fig. 5). In cross sections this slit is seen to expand laterally into a well-developed chamber with corrugated walls composed of columnar cells furnished with a heavy coat of cilia. The folds of the dorsal wall merge into a single median fold which more posteriorly becomes continuous with the foot. Everywhere throughout this fold, and over the entire surface of each crypt, the secretion of the anterior pedal gland makes its exit in the form of a finely granular, almost homogeneous substance with a strong affinity for haematoxylin dyes.

The posterior pedal gland is moderately developed, and in the form of a slender rod of cells on each side of the mid line continues from the anterior pedal gland to the cloacal opening. The foot itself presents the usual wedge-shaped form, accompanied on each side by a non-spiculose hypodermal layer, both structures serving as the outlet for the secretion of the gland.

The atrial opening, holding the customary subterminal position, leads into a cavity possessing essentially the same relations as in various other species of neomenians. Two horseshoe-shaped ridges, an internal and external, surround the cirrose area and after uniting posteriorly gradually shade into the folds of the pharynx. The component cells are slender, columnar elements moderately ciliated and are supported by a framework of muscle and connective-tissue fibres penetrated by slender blood sinuses and a few nerve bundles from the adjacent ganglionic mass. The cirri are prominent, finger-shaped structures, arising from separate bases or united into groups of from two to four, and are composed of low columnar or cubical cells ranged about a slender cavity too small to admit of the entrance of blood corpuscles though containing delicate fibres of unknown character.

A short distance posterior to the cirrose area the pharynx arises as a circular tube of somewhat smaller diameter than that of the atrial cavity. At the outset its walls are fashioned into numerous longitudinal folds, especially along its lateral and dorsal surfaces. Approximately halfway back to the radula a heavy fold develops in the dorsal wall, and sections show it to be packed with innumerable lobules of what probably is the dorsal salivary gland. These lobules are cirrus-like masses composed of relatively small cells whose secretion stains a light pink after treatment with haematoxylin. Slender ductules from the component cells make their way through the adjacent muscle fibres and open by intercellular pores throughout the entire surface of the dorsal fold.

The pharynx beneath the outlet of the dorsal fold is ventrally produced

into a deep pocket, which posteriorly develops a slit-like cavity functioning as the outlet of the ventral salivary glands. In the mid line between the salivary ducts the epithelium becomes more columnar and may function as a subradular organ, as in *Proneomenia hawaiiensis* for example. A commissure from the labiobuccal system passes in close proximity to it, but beyond this fact there is nothing to indicate its function. The ventral salivary glands are long, tubular organs, about one eighth the diameter of the body in thickness, and contain a lumen of unusually large size. The component cells, on the other hand, are relatively small and are densely packed with granules staining a dull pink after treatment with haematoxylin.

The mid section of that portion of the pharynx posterior to the outlet of the dorsal salivary gland is the seat of the radula whose musculature and relations to other organs are unique in this genus. In common with other Glossophora the teeth are developed by clearly differentiated odontoblasts on a well-defined basement membrane, and as far as can be judged from a careful examination of cross sections number nine in each row. There are probably not less than twenty-five rows. The median tooth is triangular with a base whose length is approximately twice the height. Each admedian tooth is likewise triangular with the base not over half that of the foregoing but with a height fully as great. The lateral teeth are more spike-like, and like the admedian are slightly twisted. These data, however, are largely derived from the study of fragments and are doubtless incomplete.

Beyond the narrow section where the fully developed teeth are fully exposed in the pharynx the remaining portion, comprising fully half the total length of the lingual ribbon, is bent backward and occupies the cavity of a large diverticulum of the pharynx ventral to the radula proper (Plate 7, fig. 5). As noted presently this ventral sac is operated by several heavy muscles, whose relations have been determined with a fair degree of accuracy, though their mode of operation is not wholly clear. The position of this entire radular system in the present specimen indicates that it is in a contracted state, and it is probable that in the act of feeding the pharyngeal tube is not only widened considerably, but that the radula is projected anteriorly borne on the summit of the ventral diverticulum. This will become more intelligible after the muscles concerned have been described.

The entire outer surface of the ventral diverticulum is in contact with a sheath of circular muscles of great thickness especially in the mid section (Plate 7, fig. 4, 6). This sheath is pierced at the blind end of the diverticulum by two

well-defined muscle bundles (Plate 7, fig. 6) which are attached to its wall and on the other hand are fastened to the two pairs of globular radular supports located beneath the posterior end of the radular sac. The blind extremities of the radula and the ventral diverticulum are thus closely bound together. It is probable therefore that the contraction of the circular muscle sheath results in a lessened diameter and an increased length of the diverticulum whose free extremity is thus pushed forward into the anterior section of the pharynx. This process is doubtless aided by the action of two pairs of muscles that appear to act as protractors. The more conspicuous of these is attached to the globular radular supports and extends forward, expanding in a fan-like fashion, before becoming inserted in the radular sac (close to the exposed teeth), the adjacent wall of the pharynx and to a greater extent in the anterior end of the ventral diverticulum. The second pair of protractors is relatively small, and from their insertion in the circular coat of the mid section of the diverticulum extend forward and downward to become attached to the ventral wall of the small *cul-de-sac* into which the ducts of the ventral salivary glands open. The retractors are likewise four in number. The first and most posterior pair is attached to the median radular supports and extending posteriorly and ventrally unites with the body wall. The more ventral pair is attached to the ventral diverticulum, close to the insertion of the ventral protractors, and after pursuing a ventral and backward course also fuses with the somatic musculature.

The stomach-intestine presents no especial features of interest beyond what is sufficiently illustrated in the reconstructions of the anterior and posterior ends of the body (Plate 7, fig. 5, 7). A well-developed, non-sacculated anterior cecum extends from the termination of the pharynx to the brain region. The main gut is provided with the customary ciliated tract adjacent to the gonad, and elsewhere is furnished with high columnar cells charged with a granular secretion which is periodically discharged by constricting off the distal extremities of the cells. In the region of the pericardial cavity the sacculations disappear, the gut becomes approximately circular in outline and as a relatively wide canal opens into the cloacal chamber.

The pericardial cavity is a comparatively large space typically located in the posterior end of the body. The heart likewise is well developed (Plate 7, fig. 7), and is fashioned into two chambers communicating by a narrow pore apparently guarded by a valve. The posterior division, presumably the auricle, is comparatively thin-walled, distinctly less so than the anterior division, and both are spanned by delicate trabecular muscles.

The vessels to the gonad, and the communication of the dorsal vessel or aorta with the channels in the head region are of the usual type. These last named sinuses are relatively small yet can readily be followed past the anterior pedal gland and about the buccal wall to a small ventral median sinus originating immediately posterior to the outlet of the anterior pedal gland. Above the forward end of the foot this median sinus is of more than usual width, but throughout its entire extent to the posterior end of the body it communicates here and there with the overlying visceral sinus. As the hinder end of the animal is approached these two blood spaces unite at more frequent intervals and finally fuse completely. The single channel thus formed communicates with the posterior end of the heart.

No distinct branchial apparatus exists in this species. The walls of the cloacal chamber are smooth and ciliated, and as they are in intimate contact with the visceral sinus they may function in the respiratory process.

The present specimen, although of considerable size, is sexually immature, and it is altogether possible that during the breeding season the general appearance of the accessory reproductive apparatus may be considerably altered, though the configuration of the component organs will probably remain about as that shown in the reconstruction (Plate 7, fig. 7). The gonad exists in the form of two slender tubes ending blindly anteriorly and separated widely by the dorsal aorta. Posteriorly they enter the pericardium, whose size and general appearance in sections are similar to what has been found to exist in *Strophomenia*. The gonoducts, in the form of slender tubes, arise from the posterior border of the pericardial cavity and extending downward and forward join the shell gland or ventral section.

The dorsal section of each coelomoduct is a tube of approximately even calibre throughout (Plate 8, fig. 6), and is composed of cubical cells, possibly ciliated and certainly without any signs of glandular activity. The ventral section is of somewhat larger size, and is likewise formed of cubical cells in which there are very small quantities of a darkly staining secretion. At the junction of the dorsal and ventral sections a small sacculation may represent the characteristic seminal receptacle though it contains no spermatozoa.

Ventral to the coelomoducts are two diverticula each of which communicates with the cloacal cavity and probably contains a spicule though the process of decalcification has wiped away all traces. Retractor muscles attach to the outer surface of the blind end and on the other hand extend anteriorly to become inserted in the body wall. Protractors likewise attach themselves to the sheath,

though more posteriorly, and following along the walls of the sheath are inserted in the forward border of the cloacal chamber wall.

Owing to the fact that the sheath surrounding the larger nerve bundles stains with unusual clearness, considerable care has been taken to trace out the more important trunks. The brain, holding the usual position dorsal to the pharynx, is more than usually globular and lacks the customary groove in the region of the commissure connecting the nerve cells of the two sides. From its anterior face the usual three pairs of nerves take their origin, and after connecting immediately with small, spherical ganglia are distributed to other ganglionic masses attached to the external surface of the atrial wall.

From the sides of the brain the lateral, pedal, and labiobuccal connectives originate as separate, distinct roots. At the point of union of each lateral connective with the ganglion there is a well-defined enlargement which anteriorly gives rise to a strong fibre passing forward and closely applied to the somatic musculature. In the neighborhood of the atrium and atrial ridges it branches repeatedly and the resulting subdivisions give evidence, in some instances at least, of uniting with ganglia in the neighborhood of the cirri. From this same anterior enlargement a small nerve arises and passing ventrally becomes lost in the region of the outlet of the anterior pedal gland. The anterior end of each pedal ganglion is likewise developed into a globular enlargement from which one or two nerves arise that soon become lost in the surrounding muscle tissue. It may be mentioned that the lateral and pedal connectives are each united by a small connective in close proximity to the brain.

The labiobuccal ganglia are ellipsoidal bodies occupying a space between the muscles of the radula and the lateral portions of the overhanging stomach-intestine. There is developed, from the anterior surface of each, a strong nerve, the labiobuccal connective, which in the contracted state of the present specimen is considerably twisted throughout its course to the brain. About one fourth of the distance from the ganglion to the brain each of these connectives enlarges considerably, though apparently without the presence of ganglion cells, and gives rise to three distinct nerves. One of these pursues a course anteriorly, and imbedded in the muscles of the gut unites with a corresponding branch from the opposite side, thus forming a commissure. Throughout its course at least three pairs of small nerves are developed which often branch repeatedly before being lost to view in the surrounding muscles. The other two nerves springing from the labiobuccal connective pass ventrally where one becomes lost when lateral to the outlet of the ventral salivary gland. The

other passes beneath the duct and forms a commissure. No signs of ganglia exist along this ventral commissure, and accordingly there are no indications that it forms a subradular system as might be suspected from its position. The labiobuccal ganglia are also united by the usual commissure crossing over the dorsal surface of the radula.

In the posterior end of the body both the lateral and pedal ganglia terminate in well-defined enlargements which are united in typical fashion by connectives. A few small nerves from the pedal enlargements extend posteriorly and become lost in the somatic musculature. In addition to the suprarectal commissure the posterior end of each lateral ganglion gives rise to two main nerve bundles whose ultimate ramifications form a plexus over a considerable portion of the posterior end of the animal. Only a small portion of this network has been followed in detail, but there are indications that it exists beneath the somatic musculature, behind the level of the posterior end of the pericardium. Small ganglionic masses occur at the nodal points. It may be added that this net extends across the mid-dorsal line, at least in the neighborhood of the dorso-terminal sense organ, thus forming a species of suprarectal commissure though of a diffuse type. A careful examination of the nerves innervating the dorso-terminal sense organ shows that they have their origin in the more anterior of the dorsal commissures, which accordingly corresponds to the usual one in neomenians generally. Simroth mentions two dorsal commissures in *Pro-neomenia* but as no figure is given a further comparison is not possible.

***Strophomenia agassizi*, sp. nov.**

Five specimens of this species were dredged southeast of Nantucket, Mass. (Sta. 2046A) at a depth of 407 fms., and four additional specimens were taken to the northeast of this point (Sta. 2528A) in water 677 fms. deep. In every case the animal was coiled about the branches of an alcyonarian coral, *Acanthogorgia armata*. Two of the specimens from Sta. 2046A are in the act of copulation, the posterior ends being applied to each other so that the cloacal openings are in communication with each other (Plate 1, fig. 1). In alcohol the color is light brownish yellow. The largest specimen is 37 mm. in length and 1.5 mm. in average diameter, while the smallest is 22 mm. long and 1.1 mm. in thickness. In the only specimen sectioned two dorso-terminal sense organs are present (see section on nervous system).

The cuticle surrounding the body measures, along the sides of the animal, approximately 0.19 mm.; along the dorsal side it is slightly thicker.

Innumerable spicules are buried beneath its surface and form, roughly, seven or eight layers. The greater number of spines, hollow, needle-like, slightly curved structures rounded at both ends (Plate 1, fig. 3) form two series crossing about at right angles. Among these are many radially directed spicules, likewise hollow but with the basal extremity truncated or slightly rounded (Plate 1, fig. 3).

The hypodermal cells are small and their boundaries indistinct, yet there are many examples of spicule formation where several cells may be seen attached to the base of the spine, and again many cases where but one cell has been detected attached to the radially directed spicules. In examples of the first class the matrix cells lose their connection when they become non-functional.

The papillae (Plate 1, fig. 2), each attached to the hypodermis by a relatively thick stalk, are numerous and are crowded together at the surface of the body. In the expanded portion are a number of nuclei, twenty is the average of six examples, and with these there are frequently darkly staining globular masses that appear to be some glandular product.

The anterior pedal gland, while extending from the brain to an even greater distance beyond the outlet posteriorly, is in reality not a voluminous structure as the cells are not compactly arranged nor do they fill to any great extent the visceral cavity. Owing to the fact that the secretion stains an inky hue in haematoxylin nothing has been determined regarding the finer structure of this organ, which otherwise presents no especially noteworthy features.

The outlet of the anterior pedal gland (Plate 1, fig. 4), though not especially voluminous, is of considerable length. Its walls, as usual, are ciliated but otherwise are unmodified save that they are produced into a fold, on each side of the cavity, that becomes gradually lower and finally disappears posteriorly. Halfway back the foot appears as a low ridge in the mid line, that soon reaches its average size, and posteriorly is continuous with the cloacal chamber.

The posterior pedal gland differs from the anterior merely in size, and otherwise requires no further description beyond the statement that it disappears an unusually long distance from the posterior end of the foot (in the specimen studied, opposite the posterior end of the pericardium).

The atrial opening, subterminal in position, leads into a relatively large cavity provided, in typical fashion, with ridges and cirri. Of the former the innermost is considerably larger though the cells composing it are on the average of less height than those of the inner ridge. As may be seen (Plate 1, fig. 4)

these folds unite posteriorly and bound the cirri, relatively thick, finger-shaped processes that appear, with very few exceptions, to be attached separately to the atrial wall.

What is probably the true mouth opening occurs in the postero-lateral atrial wall and leads into the long pharynx characteristic of *Strophomenia*. At the outset the walls of the pharyngeal tube are relatively thin, numerous radial muscles attach it to the body wall, its epithelial lining is developed into many low folds and a very few gland cells are scattered over its surface. Passing backward one third of its length it will be found that the radial muscles disappear, the circular and longitudinal muscles become more abundant, the tube grows more circular and multitudes of pyriform gland cells, arranged in lobules, appear upon its outer surface. This state of affairs continues to the stomach-intestine.

A radula is present, but it is of small size and stains so faintly that even under high magnification it is difficult to interpret its true form. It contains a small number of transverse rows, appears to belong to the distichous type, and in one section there are evidences that each tooth is comb-like with five sharply pointed cusps.

As in other members of the genus there are two, long tubular ventral salivary glands opening on each side of the radula into a shallow depression in the pharyngeal wall. Each of these organs consists of two divisions (a) a slender duct leading from the pharynx to the distal end of the gland where it ends blindly, and with the exception of a small division in close proximity to its outlet this canal is covered by (b) a sheath of gland cells which probably pour their secretion through intercellular channels into the central canal.

While the transition from the pharyngeal epithelium to that of the stomach-intestine is abrupt the muscular coat about the pharynx passes for a considerable distance over the ventral surface of the stomach-intestine proper and the anterior intestinal coecum. This last named organ is highly developed, possesses digestive cells and lateral pouches like those of the succeeding sections of the gut and extends anteriorly as far as the forward border of the atrium. Throughout the body the character of the mid-gut is constant, the pouches especially being remarkably regular. Ventral to the gonad the digestive cells are replaced by low, cubical ciliated elements that beneath the pericardium form an extensive tract. As the gut narrows this tract grows circular as it forces its way between the halves of the shell gland and the ciliated elements approach the mid-ventral line of the gut to become the only lining of the rectum. Near its

outer opening the intestine becomes almost square in cross section (Plate 2, fig. 7) and opens with the shell gland into the cloacal chamber.

The heart is a long tubular organ that near its posterior end falls into two divisions as in a few other species of this genus. The aorta, as it springs from the forward end of the heart, is of large size but as it courses anteriorly it assumes normal proportions, and the route it follows and that of the blood after leaving the head region, are typical in all essential particulars, save that the visceral cavity is of more than usual proportions owing to the absence of the usual amount of connective tissue.

In the midst of connective tissue and muscle fibres tracing out the distribution of the smaller nerves is an arduous and time consuming task but when these last named elements are free in the visceral cavity they may be followed with exceptional facility and their study has yielded some interesting results. The brain (Plate 1, fig. 4) not only holds the usual position but gives rise to the customary three pairs of nerves leading to ganglia about the bases of the cirri and in addition originates the lateral, pedal, and labiobuccal connectives. Those passing to the cirri are in nowise peculiar and the same is true for the connectives save that they are more than usually separated as they pass out from the brain, the lateral and pedal laterally and the labiobuccal close to the mid line near the posterior border of the brain.

The lateral ganglia are of approximately even calibre, showing no especial enlargement where they unite with the connective from the brain. In the case of the ventral cords, on the other hand, such a swelling occurs and marks the point from which the first latero-pedal connective takes its rise. Beyond this point connectives and ventral commissures occur with considerable regularity, the latter being usually of slightly larger diameter. In practically every case in the anterior and posterior ends of the body (the middle portion of the body was not sectioned) delicate branches pass from the connectives to the body wall where they disappear from view among the somatic muscles. Other nerves, usually of larger size, originate from the lateral cords and may pass dorsally or ventrally, but in every case they become lost in the body wall without being continuous across the mid line.

The labiobuccal connectives, lightly resting against the sides of the pharynx, pursue their course to the neighborhood of the radula where they join the labiobuccal ganglia united by the usual heavy commissure passing ventral to the pharynx and dorsal to the radula. Anterior to these ganglia an enlargement occurs in each connective and from them two connectives arise, one situated

beneath the pharynx the other imbedded in the diffuse salivary glands passes dorsal to the gut. At one or two points between this region and the brain nerves arise from the connectives and form seemingly either dorsal commissures or a very delicate network which it is impossible to trace from sections.

In the posterior end of the body the lateral and ventral ganglia continue to hold the usual positions and to be united by connectives and commissures at fairly regular intervals. A short distance behind the level of the posterior end of the pericardium both of these ganglionic cords enlarge considerably and are united by one especially heavy pair of connectives as may be seen (Plate 1, fig. 5). Slightly in front of this another pair occurs of about half the diameter of the one behind. The remainder in this region present the usual slender appearance and are sometimes difficult to follow. In many cases they give off delicate fibres that pass to the body wall where they probably supply sense organs or are distributed to the somatic muscles.

The suprarectal commissure is long (Plate 2, fig. 6), not especially heavy and gives rise to a few very small nerves that pass at once to the rectal wall where they spread out fan-like and disappear from view among the muscle fibres. Here and there are indications of a nervous network over the surface of the rectum but from sections neither its origin nor its configuration has been determined.

The ventral commissures in the posterior end of the body are without exception of large size and are readily followed. In a few cases fibres have been seen to leave them and pass into the ventral body wall, especially lateral to the ventral furrow; and in one specimen (Plate 1, fig. 5), one such nerve unites with the ventral ganglion and originates a fibre, in the nature of a connective that follows the body wall and resting upon the accessory reproductive organs, passes dorsally and unites with the lateral cord.

The pedal cords, behind the last connective, give rise to a very few nerves that disappear at once in the mass of muscle surrounding the cloacal wall at this point. The lateral ganglia likewise are continued behind the last connective as a heavy cord apparently distributed in large measure to the cloacal wall though some branches may pass to the neighboring body wall.

As in the case of *Proncomenia vagans* this species is in possession of two dorso-terminal sense organs (Plate 1, fig. 5). Both present the same as well as the customary appearance, but their innervation is unique. In *Proncomenia hawaiiensis* a nerve leaves the exact centre of the suprarectal commissure and pursuing its course along the mid line passes into the base of the single terminal

sense organ. In the present case a nerve arises from the suprarectal commissure, on each side of the body near each lateral ganglion. These two nerves extend dorsally then posteriorly and a short distance in front of the more anterior sense organ they unite to form a single fibre that may be traced, without especial difficulty to the base of the organ. The nerve to the posterior organ arises from the lateral cord, on the left side only, behind the suprarectal commissure and making its way across the visceral cavity it finally comes into close contact with the body wall yet may be distinctly followed to the organ in question.

Whether innervation from one nerve or two is the more primitive, it is impossible to say at present, but it certainly appears to be a fact that such an asymmetrical innervation, as in the case of the posterior organ, indicates that it is either an abnormality or is from a phylogenetic standpoint a late formation.

While the presence of copulatory spines and seminal receptacles, filled with sperms, have led to the conviction that copulation takes place among the neomenians no actual example has been noted up to the present time. Definite proof, however, is now at hand, for two individuals from Sta. 2046 were in the act of copulating (Plate 1, fig. 1). Their posterior extremities were in contact so that the cloacal openings were opposite each other, thus placing the two chambers in direct communication with each other, and a whitish secretion appears to have aided the attachment in life, or at all events to have prevented the loss of sperms during the copulatory process. It was thought best not to destroy these specimens so that nothing is known regarding the course pursued by the sperms on their way to the seminal receptacles nor of the appearance of the organs most intimately concerned in the process.

In the sectioned specimen several eggs are present in the pericardial cavity and other indications suggest that the egg-laying season was at its height. Fully formed ova are in the gonad along with multitudes of sperms in all stages of development, and the canals leading from the pericardial cavity are of very large size. In common with the other species of the genus the pericardium is spacious and the coelomoducts, leaving its postero-lateral borders, are of unusually large calibre. As may be seen (Plate 1, fig. 5) the dorsal limb of each canal is externally a simple unmodified tube uniting with the shell gland close to its anterior extremity.

In close proximity to the pericardial opening there is a small, short ridge of cells of larger size than those adjoining and the nuclei are correspondingly large and the cilia longer. This soon disappears and the cells throughout the dorsal limb are lightly staining, cubical, or low columnar, ciliated, and possess

indistinct cell boundaries. The ventral section, on the other hand consists of high, ciliated elements filled with a darkly staining, granular secretion. Close to the outlet and extending a short distance along the mid-ventral line of the rectum the cells become lower and the secretion changes, in a fully developed condition, to a granular, highly refractive, yellowish product not effected by haematoxylin. The cells of the seminal receptacles are columnar, and the secretion, consisting of droplets of varying size, is of a lavender tint. Multitudes of sperms are crowded against their free surfaces and in many cases have produced a vacuolation and even disintegration so that spermatozoa may enter such cells.

Nierstrassia fragile, sp. nov.

Eleven specimens of this species, all unattached, were dredged off the coast of New Jersey (Sta. 2588A) at a depth of 479 fms. where the bottom consisted of green mud. The smallest measures 2.5 mm. by 0.75 mm., while the largest is 5 mm. long by 1 mm., the greatest thickness. This material, very well preserved, was taken in 1885, and for over twenty years remained in an ordinary cork stoppered bottle so that its yellowish brown tint is probably due to tannin. A silky layer of delicate spicules, rather easily dislodged, gives the animal a light frosted appearance. While the spines adjacent to the ventral furrow overarch it the greater number are directed diagonally away from the furrow in a postero-dorsal direction, those along the mid-dorsal line meeting each other without, however, forming any marked keel. While a dorso-terminal sense organ appears to be present the obliquity of the sections (the posterior end of the longitudinally sectioned specimen was lacking) and a number of small folds in the hypodermis renders it difficult to definitely decide this point.

In some respects the hypodermis, cuticle, and single layer of spines show a striking resemblance to the same elements in species belonging to *Chaetoderma*. The spicules show this most clearly, having the characteristic leaf-like form with a longitudinal keel. By far the greater number of hypodermal cells (Plate 6, fig. 2) are unmodified more or less cubical elements. In some instances a small, compact mass, attached to the base of some of the spines, may represent a degenerate spicule-matrix cell, but in most instances these have disappeared. At rare intervals slender cells, possibly sensory, occur among the larger hypodermal elements but no especial nerve supply has been detected. No structures corresponding to papillae are present, the general appearance of hypodermis and cuticle over the body being represented in the drawing (Plate 6, fig. 2).

The outlet of the anterior pedal gland consists of a simple, hemispherical

depression provided with long cilia (Plate 6, fig. 8), lying behind the mouth or atrial opening from which it appears in surface views to be separated by a very narrow cuticular bridge continuous with the general investment of the body. The gland itself, occupying the visceral cavity halfway up the sides of the body, extends from the anterior end of the animal to a point about level with the posterior end of the radula. The cells composing it are pyriform, filled with a darkly staining secretion, among which are larger, lavender colored masses, apparently consisting of more than one cell. This may be one stage of glandular activity though it appears to be a different secretion.

The foot (Plate 7, fig. 1) arises immediately behind the outlet of the anterior gland in the form of a single fold that, accompanied by the usual pyriform gland cells, extends to a point a short distance in front of the cloacal opening.

The mouth opening is, as usual, subterminal in position (Plate 6, fig. 3), and in some specimens is reduced to a very small pore scarcely larger than in some species of *Chaetoderma*, while in other cases it is more or less open. In any event it leads into a small chamber holding the position usually occupied by the atrium, but it is somewhat doubtful if it should be interpreted as such. So far as can be detected after careful examination there is no trace whatever of any cirri or atrial ridges, and as the cells lining this space are in large measure at least clearly modifications of those present in the undoubted oesophagus or pharynx it would appear that the atrial chamber is wholly wanting. On the other hand it is important to note that the usual nerves passing out from the forward surface of the brain connect with masses of ganglion cells, probably the homologue of those about the bases of the cirri in other species, and from these masses fibres may be distinctly followed to the bases of some of the cells lining the cavity in question. According to the nerve supply the atrium exists, but judging from cell characters alone it is absent. On which of these criteria dependence is to be placed it is difficult to say though personally I am inclined to take the first named position.

As may be seen (Plate 6, fig. 9) the cells of this first section of the canal are of two, possibly three distinct varieties, club-shaped elements, usually long and slender especially on the dorsal surface, and thread-like supporting or sense cells. In the first type the distal portion is almost wholly occupied in preserved material by a vacuole, the nucleus occupying the basal section. The supporting or sensory cells likewise usually possess basal nuclei, but especially near the antero-dorsal boundary of the cavity some are more distally situated. Often the free surfaces of all of these cells are covered with a yellowish brown,

homogeneous substance which extends between the cells far down toward their bases. The origin of this substance could not be determined. Neglecting differences in size these types of cells form the epithelial lining as far as the opening into the stomach-intestine.

As far back as the stomach-intestine, the digestive tract is surrounded by a layer of circular muscles among which numerous radial strands occur, extending to the body wall. Among these elements, from the anterior end of the animal to a point a short distance behind the brain, numerous solitary, pyriform gland cells occur and open by intercellular pores into the digestive tract. In some instances the secretion is abundant, the small spherical granules staining intensely, but especially behind the brain the granules become relatively smaller in size and amount, vacuoles occupying a considerable portion of the cell.

A radula, of the distichous type, is present, and so far as may be determined from sections comprises 15 rows. The form of each tooth is represented in Plate 2, fig. 10, while the radula sac and odontoblasts are faintly shown in Plate 6, fig. 3. In this last figure a small ridge, composed of slender cells, occupies the position of the subradular organ, but while it presents the appearance of a sensory area no definite ganglia have been found in connection with it.

Paired ventral salivary glands are present in the form of small, globular sacs (Plate 6, fig. 3) that on one side at least develop small lobes. One of these is unusually swollen in the longitudinal section and appears to contain a few parasites. The cells are relatively small, vacuolated and in some instances contain a finely granular secretion.

The stomach-intestine exhibits the usual sacculated form and relations to other organs; and the glandular epithelium is not essentially different from that of other neomenians. In the longitudinal sections large numbers of some parasitic protozoan are present in various stages of development and may be responsible for the unusual size of some of the epithelial cells. Posteriorly the canal narrows, becomes laterally compressed as it passes between the limbs of the shell gland and then in the form of a very slender canal makes its exit into the cloacal chamber. As these animals came in unattached with no food in the digestive tract there is nothing to indicate the nature of their habitat.

Owing to the abundance of connective tissue in the visceral cavity it is very difficult to accurately trace the course of the blood, but in its main features the circulatory system is typical. The heart, much contracted, is a tubular structure (Plate 6, fig. 5) in two divisions possibly separated by a valve though this was not clearly demonstrated, and throughout much of its extent it is free

from the pericardial wall. In the first part of its course the aorta is of relatively large size, but later becomes greatly compressed and difficult to follow between the halves of the gonad. In the head region it loses its walls, the blood entering sinuses that apparently have the usual relations.

As in the case of the circulatory system the abundance of connective tissue masks the course of the smaller trunks of the nervous system so that the broader features only have been worked out. The brain presents the usual characters, giving off laterally the pedal, lateral, and labiobuccal connectives, and anteriorly, nerves which at once attach to groups of ganglion cells. As noted in connection with the digestive tract these last named ganglia probably correspond to those located about the bases of the cirri in other neomenians, and in the present species they send off fibres that pass to the anterior section of the alimentary canal whether it be an atrium or not. The pedal, lateral, and labiobuccal ganglia and their connectives are normally placed, and as many points throughout the body the first two are united by the usual commissures and connectives. In the case of the labiobuccal ganglia the commissure was followed posterior to the radula, but the abundance of muscle and connective-tissue fibres makes it impossible to determine if there be other commissures or a subradular system.

In the posterior end of the body the pedal ganglia gradually diminish in size and finally disappear from view. Almost to the end of their course they continue to be united by connectives with the lateral ganglia, but these show no unusual development and the pedal ganglia lack the posterior enlargements characteristic of some neomenians. The lateral ganglia, on the other hand, terminate in globular masses, in the neighborhood of the pericardial-coelomoduct openings, that are united by a commissure passing dorsal to the rectum where the latter unites with the more expanded section of the gut.

The paired gonad, containing both ova and spermatozoa, extends as usual, from about the level of the anterior end of the foot to the pericardium. In both specimens the ova appear to be somewhat immature while the spermatozoa are in all stages of development and especially in the mid section of the gland are so numerous that they distend its walls to a considerable degree. Posteriorly the halves of the organ gradually narrow, diverge slightly and communicate with the small pericardium.

The opening of each gonoduct is borne on the summit of a small papilla (Plate 6, fig. 5) on the postero-lateral walls of the pericardium, and leads into a tube which passes laterally and then posteriorly to unite with the ventral

section, or shell gland. For a distance equal to about one fourth of its length the dorsal half of the gonoduct is a simple, very slender tube but at this point it enlarges somewhat and develops a short pouch-like diverticulum composed of cubical, ciliated cells without any special signs of glandular activity. Continuing its way forward for a short distance another diverticulum, finger-shaped in appearance, arises and on both sides of the body is directed backward and downward. In the usual position for the seminal receptacle a very slender tube appears, on each side of the body, that is directed anteriorly for a short distance and terminates in a slight enlargement. These three pairs of diverticula are empty and accordingly afford no clue as regards their possible function. The cells of this dorsal section of the gonoduct are all more or less cubical, ciliated but without ridges or other modifications.

The shell gland, (Plate 6, fig. 5), composed of the usual long and slender cells, occupies the usual position. Posteriorly the halves unite to form a single median section with folded walls, but the union is unusually near the opening into the cloaca. Lying ventral to this portion of the reproductive system there are two bundles of spicules, five in each group, that are developed and concealed in two diverticula, arising not from the cloaca, as is usual, but from the undivided section of the shell gland. Each of these spicules is rod-shaped, apparently straight with the base rounded and the distal extremity pointed, and during the act of copulation is probably protruded through the reproductive opening into the cloaca. As may be seen (Plate 6, fig. 7), the median section of the shell gland and the adjoining undivided portions together with the bundles of spicules are imbedded in a relatively large diverticulum, rich in muscles, that in life may doubtless be protruded beyond the opening of the cloaca.

In reality the cloacal chamber is comparatively large but usually it is almost completely filled by the great diverticulum bearing at its tip the reproductive opening. In some specimens it is partially closed and in other cases its margins are widely expanded. Throughout the greater part its walls are smooth and unmodified but beyond the reproductive and anal openings five or six low ridges (Plate 6, fig. 4) make their appearance, and while they may be respiratory they certainly possess some additional unknown function since the pyriform cells are highly glandular and their distal extremities are filled with a colorless secretion after treatment with haematoxylin. In the neighborhood of the anal opening additional groups of cells occur, and in some instances appear to open into the cloacal cavity, but the supposed ductules may in reality be delicate strands of connective tissue.

EMBRYOLOGY.

In the report of the Solenogastres of the North Pacific a species of neome-nian, *Halomenia gravida*, was described that carried in the spaces between the branchial folds of the cloacal chamber twenty-five embryos in various stages of development. As the single specimen was sectioned before these were discovered it is obvious that the following account of the early growth of this species has been based solely on sections and reconstructions. It may be said, however, that unusual care has been exercised in their study, and while certain details, to be noted later, are doubtless faulty, the broader features are fairly clear and intelligible.

In the earliest stage two distinct nuclei are present (Plate 13, fig. 5) together with four other bodies that may be nuclei, though appearances (Plate 13, fig. 10), suggest that more probably they are unusually large yolk granules superficially coated with a dense layer of protoplasm or some glandular secretion. The egg measures at this time 0.32 mm., assuming that a slight elongation is due to the pressure of the neighboring branchial folds. A single polar body (Plate 14, fig. 10) is attached, and it is a peculiar fact that in every case where these cells have been seen there is never more than one. A delicate membrane, cuticular in appearance, surrounds the egg, and where it has remained undisturbed it is closely adherent to the yolk granules beneath. At other points on the surface it may be thrown into folds, but as these lack regularity and any signs whatever of nuclei, it is probably a vitelline membrane and not a chorion, though this last named structure occurs normally in the Chitons and several Solenogastres. Furthermore in developing ova within the reproductive gland of *Halomenia* there are no traces, even in early stages, of a chorion though the cuticular membrane just described is well defined. Immediately within the membrane, and adjacent to the polar body, a clearly defined nucleus exists closely surrounded by yolk with the exception of an excentrically placed archiplasm mass. It is probably the female pronucleus, while the remaining one of similar appearance is the sperm nucleus.

In the only other early stage two undoubted nuclei hold the same relative positions, and again there are four bodies that as before may be either nuclei or yolk granules. It is worthy of note that one or two similar bodies may occur in fairly advanced embryos, and on the other hand none of these bodies has ever been detected in mature ova within the gonad. Furthermore in these early stages no cleavage planes have been noted.

In the next stage segmentation has commenced, resulting in twenty-eight cells (Plate 13, fig. 13). These show no differentiation into micromeres and macromeres, and so far as may be judged from sections the inequality of size noticed among the cells is irregular and not confined to a definite hemisphere. All of the cells are closely crowded together and consequently no sign of a blastocele exists (Plate 14, fig. 11). These facts together with the absence of polar bodies in this particular embryo and the uniform distribution of yolk renders it impossible to distinguish the principal axes.

In the succeeding stage (Plate 13, fig. 6) approximately one hundred nuclei are present and an elongation of the larva defines the principal axis. There are, however, no definite signs of blastopore or blastocele, and the size and arrangement of the cells does not certainly define the dorsal and ventral surfaces. Sections (Plate 14, fig. 8) show that at this stage several cells are wholly enclosed within the partially formed external layer whose component cells are of unequal size and irregular arrangement. In a few cases the position of karyokinetic spindles indicates that the internal cells are formed by tangential divisions, a species of delamination, while other cleavages at right angles to these further increase the number of cells on the exterior.

In advance it may be said that in the larvae of this species test cells partially enclose the body as Pruvot ('90) has shown to be the case in *Myzomenia banyulensis*. While no definite reliance can be placed on reconstructions for determining the exact shape and arrangement of cells it nevertheless appears fairly well established that in the stage under consideration the external cells are not so definitely arranged as in the later stages, and even there they are not so diagrammatically placed as in Pruvot's figures.

In the next stage (Plate 13, fig. 12) a single polar body remains in place, held by the vitelline membrane, and the animal pole is thus determined, together with the probable point of origin of the cerebral ganglia though these last named structures have not as yet put in an appearance. The differentiation of the test cells has become evident to a certain extent, although their exact limits have not been determined from reconstructions. Granted that the polar body has not shifted from its point of origin, it does not appear to mark the centre of the test cells which may be seen (Plate 14, fig. 1) to extend over nearly the entire dorsal surface. Furthermore while the test cells may form rows or definite bands about the embryo, reconstructions give no clear evidence of this fact up to the present point in the development.

In sections the cells, exclusive of those forming the test, that is those destined

to develop into the fully formed animal, are much more numerous than before, and are as yet without signs of differentiation into the fundamentals of the various organs. This statement may perhaps be modified in one particular, for on the ventral side immediately posterior to the large test cells is a group of several elongated cells extending from the surface to a considerable distance into the interior. Their external position is marked by a shallow depression (Plate 14, fig. 9), and appearances suggest that this is the region of the blastopore, and that the cells are stomodeal elements destined to become much more numerous and prominent in later stages. As may be seen in the figures no definite blastocoele is evident.

Later stages are ushered in with the development of the test (Plate 13, fig. 11), the great increase in the number of the remaining ectoderm cells, and the appearance of a definite stomodaeum, mid-gut, and cerebral ganglia together with the appearance of recognizable mesodermal elements. In other words, differentiation has now advanced to a stage where the three germ layers are clearly defined, and certain systems broadly outlined so that the following account will probably gain in clearness if these various systems are considered individually rather than parts of the whole.

The Test:—As has been noted some of the test cells have been seen to arise at an early stage by tangential divisions of the relatively few cells composing the body of the embryo. Concerning the cleavages of cells left in the interior there is nothing known. The differentiation of the test itself from the remainder of the ectoderm of the trunk region is accomplished by a slower rate of division that is soon brought to a complete standstill. As may be seen in the figures (Plate 13, fig. 11, Plate 14, fig. 3), the test extends at the outset farther over the ventral side than on the dorsal, but in the latest stage in the present collection (Plate 14, fig. 4) a shifting has evidently occurred as the brain is placed at the anterior end of the embryo, and the mouth is well forward on the ventral side. Even yet the organ is asymmetrical in position, but more radially adjusted than at first. Judging from the amount of yolk, contained in the test cells of the oldest embryo it is evident that a very considerable time must elapse before the nutritive material is absorbed and the remnants cast off. While the nuclei present an irregular, somewhat shrunken appearance the cytoplasm is not vacuolated, as are functional test cells of *Chitons* or *Yoldia* for example, and it is probable that a much greater diminution in size occurs before these elements become wholly non-functional and worthless.

That a diminution in the size of the test has already ensued in the oldest

larva is evident from a comparison with the figures of earlier stages. In the oldest larva the increase in the size of the body is not especially marked, and yet the test does not compose more than half of the external surface. Measurements, somewhat roughly made, indicate that a shrinkage of approximately two fifths of the original superficial extent of the test has taken place. To what extent this progresses is not known; nor is it known what means are employed to increase the area of the remaining ectoderm. In a few cases cells of the trunk ectoderm have been seen, containing karyokinetic spindles thus indicating one source of increase. On the other hand there are certain large, yolk containing cells in the anterior end of the body of the oldest larva (Plate 14, fig. 4) that do not appear to belong to the mid-gut. From their position it is altogether possible that products of these are added to the external layer as the free border of the test advances toward the apical pole. There is no indication other than this of an ectodermic layer beneath the test, and the indication is that at the time of its dehiscence the test is a comparatively insignificant organ.

Nervous System:—In the earliest recognizable stage the cerebral ganglia appear (Plate 14, fig. 6) as a set of cells bordering a depression in the test. It is evident that originally one or more cells, indistinguishable in sections from those of the test, underwent cleavages in which the plane of division cut the surface of the body at right angles. The resulting elements migrated some distance into the interior of the embryo, and at a later time other cells were cut off from these parent cells that remained in contact with the depression. By the successive divisions of daughter and parent cells a large accumulation is produced, extending from the exterior to the neighborhood of the stomodaeum. Within a comparatively short time wing-like prolongations are developed which encircle the stomodaeum and still later these are continuous with a rod-like mass resting against the ventral ectoderm and extending to the posterior end of the body (Plate 4, fig. 3, 4). Unfortunately all of the sections of the later stages are longitudinal, and it is not possible to determine if this ventral band is double, as it ultimately must become if my belief is correct that it forms the ventral cords.

While the evidence goes to show that the cerebral ganglia arise at one point in the outer layer of cells, later stages indicate that the depression undergoes a considerable lateral expansion, and in one case the two accumulations, destined to form the halves of the brain, become almost if not completely separated from each other, there being two external pits in contact with the surface. In another example the nerve masses are at opposite ends of a transverse groove

and are thus incompletely separated. In the oldest stage the nerve mass is in contact with the anterior surface at one point only, and its double character does not appear until it divides to surround the stomodaeum.

Apical Sense Organ:—An apical sense organ may exist in this anterior depression from which the cerebral ganglia arise. One is present in *Myzomenia banyulensis* according to Pruvot, but in the present series of embryos there are, with one possible exception, no especially developed apical cells nor tuft of cilia. The exception is the oldest embryo where a small band of cells extends in the mid line from the ganglionic enlargement bordering upon the stomodaeum to the surface where it ends in a slight pit. The material is excellently preserved yet it is not possible to detect apical cells, and cilia have never been seen at this point or anywhere else on the body.

The Terminal Ring:—In Pruvot's figures of *Myzomenia* there appears a circular group of relatively large cells surrounding the posterior end of the body. This organ, somewhat resembling an annelid telotroch, is ciliated and a diffuse tuft of cilia projects from the enclosed, terminal depression. In some of the oldest embryos of *Halomenia* the same structure, minus the cilia, holds a corresponding position (Plate 13, fig. 11). The cells are comparatively large yolk-laden elements (Plate 14, fig. 1, 2), resembling small test cells, and are arranged about a saucer-shaped depression. At first they form two rows as in *Myzomenia*, but in the oldest embryo in my possession the ring-like arrangement has become lost, the cell boundaries have seemingly disappeared and I have not been able to detect any nuclei that may with certainty belong to these cells. The depression is likewise lacking and the yolk granules merely form a confused mass (Plate 13, fig. 9) at the posterior end of the body. In this same section the ectoderm adjacent to the "telotroch" appears to be passing beneath the yolk granules, leaving them upon the exterior, but the absence of definite cell boundaries renders this somewhat uncertain. Appearances suggest that the terminal ring is a larval organ that, like the annelid telotroch, is cast off.

The fate of the cells within the terminal ring is uncertain. In early stages (Plate 14, fig. 2) the depression is composed of yolk-bearing elements similar to those of the ring itself though of smaller size. At a considerably later stage (Plate 14, fig. 3) the cells in the corresponding position are relatively small, without yolk granules and with indistinct boundaries, and it is reasonable to conclude that they are the progeny of the cells originally included within the terminal ring. Anteriorly they are continuous with the ganglionic cord extending along the ventral side of the body. In the oldest stage the nerve cord comes

in contact with the epithelial layer in the posterior end of the body (Plate 13, fig. 9), and the only tenable theory that suggests itself is that the terminal cells of the ganglionic cords, those adjacent to the epithelium, have originated from the elements at first surrounded by the terminal ring.

While the cells of the epithelium with which the ganglionic cords come in contact form a fairly distinct group, they are not depressed and otherwise give no indication of constituting a special sense organ, although I am inclined to look upon them as the future dorso-terminal sense organ characteristic of many adult neomenians.

The Foot.—The oblique direction of the sections through the oldest embryo renders it practically impossible to determine the exact arrangement of the cells of the ventral surface. Immediately beneath the ventral rod of ganglion cells, and therefore in the mid line, the cells are clearly defined columnar elements placed approximately at right angles to the surface of the body. A short distance removed on each side the cells of this character become replaced by others of more slender appearance that are inclined toward the posterior end of the body. It thus appears that along the mid-ventral line there is a strip of cells about one sixth of the body diameter in width, that probably becomes the future ventral groove and included fold although there are no indications that these structures exist as yet. At the anterior border of this strip, and consequently immediately posterior to the mouth opening, is the anterior pedal gland, consisting of several cells bordering upon a slight depression (Plate 14, fig. 4) — the future pit-like outlet prominent in the adult. Five or six cells contain small quantities of a moderately staining secretion, and are relatively conspicuous objects.

Shell (?): As just noted the cells bordering upon the mid-ventral line are inclined posteriorly with reference to the surface of the body, and this appears to be generally true of the whole trunk region. Especially along the mid-dorsal line they are comparatively slender, columnar elements (Plate 14, figs. 3, 4), containing distinct spherical or ellipsoidal nuclei and one or two yolk granules each. In the oldest larva these have separated at fairly regular intervals, and originally I was inclined to consider the spaces thus formed as the seat of calcareous products. There is, however, a lack of any definite cuticular sheath, and no perforation or elevation of the membrane bounding the body, and accordingly I am now of the opinion that these spaces are due to methods of preparation of the material. In the posterior end of the embryo there is a distinct slit (Plate 13, fig. 9), extending through three sections or about one fifth the diameter

of the trunk, that is bounded by a delicate though none the less definite cuticular sheath. It has the appearance of a developing spine, scale or plate of calcareous material, but with one specimen only it is not possible to form a definite opinion. It is very evident that the oldest larva of *Myzomenia* as figured by Pruvot with its many scale-like plates is much more highly developed than any embryo in the present collection.

Stomodaeum:—As previously noted a few of the cells on the ventral side of the body, at the posterior border of the test, rest against a shallow depression (Plate 14, fig. 7, 8) in relatively early stages, and extend for a considerable distance into the interior of the embryo. They thus occupy identically the same position as the future stomodaeum, and it therefore becomes practically certain that the depression is the first indication of the blastopore and that the slender cells are stomodeal elements. In the next stage (Plate 14, fig. 3) in the present collection the yolk-laden mid-gut, communicating with the exterior, is directly in contact with the test cells anteriorly, but posteriorly it connects with the yolk free stomodeal cells which extend for a considerable distance within the body. The stomodaeum is thus a semitubular structure largely confined to the posterior side of the digestive tract. This same state of affairs continues in the oldest stage (Plate 14, fig. 4).

Mesoderm:—After the formation of the ectoderm the remaining cells form a confused mass within the interior. Order, that is regularity of arrangement, is not established until relatively late in development (Plate 14, fig. 3) when the mid gut is distinctly outlined. Between the gut and the ectoderm are several fairly large yolk-laden cells whose exact nature is open to question. Anteriorly, between the test and the gut, several of these appear (Plate 14, fig. 3), and in the latest stage represented (Plate 14, fig. 4) these appear in even greater abundance. They ultimately may become incorporated with the mid-gut, or in part at least they may form the ectoderm of the anterior end of the body as the test diminishes in size, or in whole or in part they may be mesoderm. In the posterior end of the body similar cells appear, of somewhat smaller size, that I am inclined to consider true mesoderm. Unfortunately the question cannot now be decided.

Endoderm:—The endoderm, as indicated in the preceding paragraph, does not become clearly differentiated until relatively late in development, judging from the material in hand. At the time that the stomodaeum communicates with the succeeding section of the digestive tract the mid-gut is clearly defined as a blind sac filling practically all of the interior of the body.

The component cells at this time are comparatively large, and as they are filled with yolk granules they are clearly distinguished from the stomodeal elements. In the latest represented stage (Plate 14, fig. 4) the mid-gut in its central portion appears as a confused mass of cells owing apparently to great irregularities in the position of the component cells. The general outline of the organ, it is believed, is correctly indicated. No trace of a proctodaeum or cloacal chamber has been discovered.

Comparisons.—The only other accounts of the development of a Solenogastre comes from the hand of Pruvot who investigated two species, *Myzomenia banyulensis* and *Proneomenia aglaopheniae*. The two reports are very brief, and in some respects the observations coincide with those of the foregoing paragraphs; on the other hand there are certain statements that are open to question. These agreements and differences will now be considered in brief.

In *Myzomenia* the eggs as they leave the gonad and enter the coelomoducts are naked. A membrane is present when the eggs leave the body, and it therefore follows that the shell gland forms the envelope. It does not follow, however, that the ducts are not at the same time excretory organs though this may indeed be the case. In *Halomenia* the ova in the gonad are surrounded by envelopes of the same character as surround the eggs stored in the cloacal chamber. The shell gland is highly developed in this species, but what part it plays in the reproductive process is not clear.

The four-cell stage comprises one large and three small cells; successive divisions of the smaller cells enclose the products of the larger. At a later period the embryo becomes cap-shaped and a large pit in the ventral half of the embryo is believed to represent the blastopore. The test now becomes clearly defined, an apical tuft of cilia arises, the trunk region, button-like in form, protrudes beyond the margin of the test and a ciliated terminal ring encloses a pit-like depression termed the blastopore. Calcareous plates arise at various points upon the surface of the body, whereupon the metamorphosis ensues.

Turning now to the development of *Proneomenia* it is evident that in several respects it bears a close resemblance to *Halomenia*. The blastomeres are described as being slightly unequal, surrounding a small blastocele. Invagination occurs and a large blastopore is formed. The larva now elongates and, covered with a ciliated coat borne on five tiers of cells forming three zones or segments, the resemblance to the *Myzomenia* larva is fairly complete. There

are, however, certain details of the process that are difficult to comprehend. A brief summary¹ will make this fact clear.

"The layer forming the primary invagination (? archenteron) does not correspond to the definitive entoderm, but gives rise to *all* the tissues of the trunk. By the tangential division of its cells, it gives rise to a superior entodermic mass resting upon a single layer of cells; the latter increases by the radial division of its cells and becomes infolded, forming three invaginations; of these the middle one, which remains open, becomes the future proctodaeum, while the two lateral ones close and are transformed into the masses of mesoderm, the lateral mesoderm-bands. The lower layer, which now has the form of a vault, represents the ectoderm of the trunk. The lips of the proctodaeum now grow out to form the caudal button which first projects into the cavity of the ectodermal vault, but later, together with the entire vault, becomes evaginated through the depression at the posterior end of the larva. This conical protuberance with the caudal button and the proctodaeum at its extremity represents the trunk of the young *Proneomenia*. The entoderm still remains as a solid mass with the mesoderm-bands on either side and in contact with the proctodaeum behind. The next important change is the appearance of three ventral invaginations of the larval ectoderm, just behind the circle of large cilia on the middle segment; the median of these invaginations, the larval stomodaeum, is merely transitory, while the two lateral ones are concerned in the formation of the ectoderm and mesoderm of the head. These two unite, forming a transverse band capping the anterior end of the entodermic mass and prolonged posteriorly at two points to meet the mesoderm-bands of the trunk; this portion appears to form the muscles, while the more dorsal elements of the invagination form the cerebral ganglia. The cells of the apical plate seem to take no part in the formation of the nervous system. The ectoderm of the head appears to form entirely from these anterior invaginations, while that of the trunk develops from the primary posterior invagination. The latter is now completely evaginated, and has developed the provisional imbricated spicules. In this way the young *Proneomenia* is developed under cover of a provisional ectoderm which serves as a locomotory organ and is thrown off at the moment of metamorphosis. The adult does not exhibit a distinct head but, during development, this structure is perfectly distinct and arises quite independently of the trunk."

Upon first thought it appears difficult to correlate some of these observa-

¹ From a note by M. F. Woodward in the English translation of Korshelt and Heider's Text-book of the embryology of invertebrates. 1900, 4, p. 19.

tions with those pertaining to the development of any other class of animals, but the difficulty, it appears to me, arises at the outset when the cells included within the test are declared to be wholly endodermic. I shall endeavor to show that they comprise the elements of all three germ layers, and that the Solenogastre development may be derived from that obtaining in the Chitons for example.

In the first place I am in entire accord with those authors, notably Drew (1901), who look upon the test as a highly developed velum. In *Ischnochiton* it is a relatively insignificant structure forming an equatorial band around the embryo and dividing the animal hemisphere from the vegetative, or, roughly speaking, the head from the trunk. Until the metamorphosis it remains functional when it is cast off. Remodelling such a type of larva into that of *Halomenia* it is necessary merely to greatly widen the band. This well nigh obliterates the usual head vesicle, leaving only those cells at the animal pole that develop the cerebral ganglia. In the vegetative half of the animal the cells responsible for the development of the trunk ectoderm are likewise greatly reduced though by no means wiped out entirely. In both types the blastopore is situated on the ventral side adjacent to the velum or test, and the ectoderm that forms the future trunk is continuous with the margins of the test.

The absolute proof of this theory rests upon a knowledge of the history of the early blastomeres, and this unfortunately is almost totally lacking. We know that the early cleavages may be nearly equal or highly unequal, but to assume that because one or more cells become partially withdrawn into the interior at an early stage it is therefore endodermal is certainly not justified. Furthermore it is unfortunate that the terms micromere and macromere have been introduced in describing the Solenogastre development since these terms apply to the history of the cells in question rather than to its size. We know that in the majority of the Trochozoa that have been carefully examined, the original four cells divide three times forming three quartettes of micromeres, some of which as a matter of fact may be larger than the remaining parent cells or macromeres which are now endodermal. Whether this is true of the Solenogastres we do not know, but the arrangement and fate of many of the cells suggests strongly that something akin to this has taken place.

Considering now the gastrulation of *Myzomenia* and *Proneomenia* it is evident at the outset that the test is of such large size that when viewed from the side it conceals within its borders the entire trunk. The so-called blastopore is accordingly nothing more than a temporary shallow depression bordered

on all sides by the test. The same effect may be produced in *Halomenia* (Plate 13, fig. 11 for example) by slightly extending the borders of the test. The layer forming this "primary invagination" is therefore no archenteron, and Pruvot is quite correct in claiming that its cells do not correspond to the definitive endoderm and that they give rise to all the tissues of the trunk. By tangential divisions of the cells of this depressed area there is produced a "superior ectodermic mass resting upon a single layer of cells," that is to say the ectoderm of the trunk becomes distinct from the endoderm that later forms the mid-gut (Plate 14, fig. 5).

In this area circumscribed by the borders of the test are "three invaginations; of these the middle one, which remains open, becomes the proctodaeum, while the two lateral ones close and are transformed into "masses of mesoderm." The proctodaeum is evidently the mid-gut, but that it is open to the exterior or is derived from this species of invagination is certainly an erroneous conclusion resulting from a failure to detect the true blastopore. The mesoderm bands are evidently the ventral cords of ganglion cells as will appear more clearly later on. Concerning the formation of the trunk it may be said that the "lips of the proctodaeum" evidently refers to the rim of the terminal depression in the trunk of comparatively old larvae and the "terminal button which first projects into the cavity of the ectodermal vault" probably refers to the group of cells that in one stage in the development of *Halomenia* (Plate 14, fig. 4) lie at the base of this depression. Later the button "together with the entire vault becomes evaginated" beyond the borders of the test, and the presumption is that the button corresponds therefore to the dorso-terminal sense organ.

In the anterior half of the body three invaginations are said to exist in the midst of the test cells. The first, a transitory structure, is said to represent the stomodaeum. If such is actually the case it occupies a very different position from what it does in *Halomenia*. That it is transitory makes it appear to be a misinterpretation. The two lateral invaginations that ultimately meet to form a transverse band are said to supply material for the ectoderm of the head, the cerebral ganglia and the mesoblastic bands that are "prolonged posteriorly to meet the mesoderm-bands of the trunk." I am not certain regarding the head ectoderm formation but the mesoderm bands are clearly the ganglionic trunks that continue to the posterior end of the body.

GENERAL CONSIDERATIONS.

Since the completion of the report on certain species of Solenogastres from the Pacific Ocean (Heath, 1911) the excellent paper of Nierstrasz (1908) and several objections (*in litt.*) on the part of various investigators open up the discussion of certain questions not fully treated in the earlier paper. It is evident, however, that some of these protests, like many of my own theoretical conclusions, are very largely based on personal opinion. The same material in the hands of these or other students would perhaps be interpreted in various ways from a theoretical standpoint, and accordingly the following paragraphs are very largely a confession of faith with some of the grounds upon which it rests.

The first of these criticisms is directed at the section treating of the formation of the spicules imbedded in the cuticle, which, like the papillae when such are present, is a product of the hypodermis or epidermis as Nierstrasz prefers to term it. At the outset it is important to note that there are two distinct modes of spicule formation, and the confusion that my account appears to have created is largely due to the fact that this has not been kept in mind. In all of the Chaetodermatina, so far as my observations go, each spine is the product of one, and only one, cell, and it may be, indeed it usually is, crowded between adjacent hypodermal (or epidermal) cells. But that these surrounding cells are limited to three, or that they perform a molding function as Wiren maintains (Wiren, '92) is open to serious question. In those sporadic cases where the matrix cell is raised above the general level of the remaining elements of the hypodermal layer the minute spine is clearly seen to rest solely upon this formative cell, and is not in intimate contact with any other cell element. The same method of growth also appears to be characteristic of the families Neomeniidae and Dondersiidae. In those species of the suborder Noemeniina where the spicules form more than one layer a relatively small number of spines are usually directed radially and at the completion of their development project beyond the external surface of the cuticle. So far as I have been able to follow the development of all such radial spicules each is the product of a single cell, which is either attached directly to the base or close to the base at one side.

In the families Proneomeniidae and Pruvotiniidae the development of the tangentially placed spines follows a different course of development, at least in several carefully studied species belonging to the genera Halomenia,

Dorymenia, Lophomenia, and Strophomenia. At its first appearance the minute, cone-shaped calcareous product rests upon a relatively large cell that probably may be considered the homologue of the matrix cell in the foregoing types. In this case, however, the matrix cell is surrounded by "seven or eight cells, slender in form, indistinct in outline, with dense nuclei and attenuated bases which are imbedded in the hypodermis proper." The cell membranes of these accessory elements are distally attached to a membrane or sheath enveloping the spine which accordingly is interrupted near the base. The part played by these different cells is obscure. The basal cell doubtless acts as a lime-secreting agent, and the remaining subsidiary cells form the spicule sheath, but whether they likewise supply calcareous material remains undetermined. The important point, however, is clear that all of these cells, eight or nine in number, are attached to the spine, diminish in size as the spine increases, and in many instances retain their attachment permanently. There is therefore nothing to indicate that they are other than matrix cells. Essentially the same mode of development has been described by Plate in his study of the formation of the spines of certain species of Chitons, and it furnishes another line of evidence for the belief that the Solenogastres and Chitons have had a common ancestor.

One point noted in the Pacific report remains obscure. In early stages a minute body rests between the basal matrix cell and the base of the spine. The point in question is whether it is a cuticular product or a cell. In a late stage it undoubtedly is cuticular, and appears to prevent the passage of lime salts from the matrix cell and by its increase and subsequent decrease and final disappearance is responsible for the development of the cavity within the spine.

At the suggestion of Professor Nierstrasz I have made a careful examination of the heart in all of the species of Solenogastres described in the Pacific and in the present report; as a result I cannot feel that much dependence can be placed on this organ as indicating relationships or relative primitiveness considering our scanty knowledge of the group. To me it appears clear that the dorsal blood vessel in the pericardial region has been provided with a highly developed muscular coat, has thus become a pulsatile organ which frequently comprises two divisions, a ventricle and auricle or atrium, as certain authors prefer to term it. In some species this muscular section lies in a dorsal fold of the pericardial wall; in other cases it has severed its connection with the wall and lies freely in the pericardium. In certain species the auricular or atrial division is very short, as in *Chaetoderma argenteum*, or it may be more pronounced as in

Chaetoderma attenuatum, and again it may be entered by two vessels but this bipartite condition ends at the pericardial wall. The impression given is that the heart is a relatively simple tube, usually with two divisions, sometimes sacculated, but I have never found more than one auriculo-ventricular opening or any other evidence to show that the heart is a paired organ.

Whether the auricle or atrium is the homologue of the auricles in other species of molluses is likewise uncertain; there is no clear evidence for or against such a view. And we are, it seems to me, equally in the dark when we approach the subject of the most primitive type of Solenogastre heart. In my opinion the heart which lies in a fold of the pericardial wall as in some of the *Proneomeniidae* appears to be among the most primitive. On the other hand where it lies freely in the pericardial cavity, as in *Chaetoderma* or *Alexandromenia*, it must have arisen from a simpler embryonic condition, and a simpler phylogenetic stage is equally conceivable. Here again the matter rests upon few data and personal opinion and must accordingly remain as an unsettled problem for the present.

The digestive system, like the circulatory and muscular systems, is most susceptible of change, and the wide variations of form and component elements, correlated with differences in habits of life of the different species, renders it difficult to differentiate coenogenetic from palingenetic characters. I believe, however, that in the ancestral Solenogastre the fore gut was provided with both dorsal and ventral salivary glands and a radula, while the mid-gut, as in the modern neomenians, was a relatively simple tube without clearly defined stomach, digestive gland, and intestine. The hind gut appears to me to be a relatively small section of the digestive tract in the *Chaetodermatidae*, and forms no part of what has been termed the cloacal, anal, or mantle chamber, a point to which I shall return. As Thiele maintains the atrium of the *Neomeniina* is no part of the fore gut, and it is possible that it is the homologue of the buccal shield in the *Chaetodermatina* and the snout of the *Chitons*.

Dorsal and ventral salivary glands clearly appear in several species, such for example as *Proneomenia hawaiiensis* and *Lophomenia spiralis*. On the other hand the ventral set may disappear completely as in *Limifossor* and several species of *Strophomenia*. Since dorsal glands exist in *Limifossor* I am inclined to look upon the diffuse glands attached to the fore gut of *Chaetoderma* as a modified homologue. Whether this is the case with the equally diffuse glands surrounding the walls of the fore gut in *Strophomenia* it is impossible to determine. In *Alexandromenia* there are three distinct groups of salivary glands one of

which with paired ducts is doubtless the counterpart of the ventral set of other species. The possible homologue of the dorsal gland here exists as a diffuse band encircling the fore gut in the neighborhood of the brain. The third set is attached to the fore gut between the radula and mid-gut, and in appearance and staining qualities differs from the other two. It is altogether possible that this posterior set is of more recent, independent origin, and it is also possible that the diffuse glands existing in various species of *Strophomenia* may have had a similar origin. But at the same time it should be kept in mind that these pharyngeal glands in *Strophomenia* lie in front of the radula and ventral salivary glands and accordingly may represent a diffuse dorsal gland.

Since a radula exists in *Limifossor talpoideus* and *Halomenia grvida*, for example, with odontoblasts and basement membrane typically located, and the entire organ holding essentially the same position with reference to the ventral salivary glands and the pharynx generally as in the Chitons, it is difficult to avoid the belief that it was present before the Solenogastres became an independent group. The radula may indeed have originated as a cuticular product of the fore gut with separate teeth or as minute projections of a more or less extensive buccal lining, but that this has been its history since the Solenogastres branched off from the parent stock is highly improbable. It is true that the radula in present day species is a highly variable structure — distichous, polystichous, with or without a basement membrane, reduced to a conical peg, or absent altogether — but in my opinion the *Limifossor* and *Halomenia* types of radulae have preserved their ancestral characters, while the others represent different stages of degeneration. This is wholly aside from the discussion as to which is the more primitive, the polystichous or distichous plan, a matter it appears to me which cannot be settled considering the small amount of comparative anatomical data we now possess.

As to the mid-gut there are wide variations and here again it is difficult to follow the ancestral history. Where the digestive gland is not clearly differentiated or the stomach or intestine sharply defined we certainly have the least complicated state of affairs and it appears to me to be the more primitive. The Chaetodermatina are therefore more highly modified in this respect than are the Neomeniina.

In this connection the so-called anal, cloacal or branchial chamber may be considered to be a development of the anus, as certain authors maintain, and nowise the homologue of the mantle cavity. The lamellae on its walls in the Neomeniina are therefore modified anal folds and according to Thiele

and Plate are not homologous to the branchiae of the Chaetodermatidae, which though a coenogenetic development have nevertheless had an independent origin. Nierstrasz likewise considers the neomenian branchiae to be anal folds, but holds that the Chaetoderma type of gill is the most extreme development of such lamellae. In the Pacific report I have argued in favor of the complete lack of homology between the neomenian type of gill and that found in members of the family Chaetodermatidae. Concerning the true significance of the first named I have no evidence to offer. Plate and Nierstrasz have described certain species (*Notomenia clavigera*, *Archaeomenia prisca*, *Proneomenia discoveryi*) in which the coelomoducts do not open into the branchial cavity, and for the present at least I am not inclined to argue for or against the theory that the neomenian gill is a derivative of the anal wall. But when it comes to the Chaetoderma type of gill the evidence that it is a development of the anal or proctodael walls is far from being conclusive. If such a type of gill were to be found among the Gastropoda I venture to say it would unhesitatingly be considered as a ctenidium. It has the same macroscopic and microscopic structure, the same blood circulation, musculature, and innervation as the Chiton or Haliotis gill for example, and the space in which it is held contains the outlets of the coelomoducts and digestive tract. So far as appearance and general relations are concerned the gills of the Chaetodermatidae are true ctenidia, and the surrounding space is a mantle cavity. Here again we must have embryological evidence to definitely settle the question.

Regarding the nature of the ventral fold there is little to add to the observations of other authors and the comments made in the Pacific report. A detailed study of the most advanced larvae of *Halomenia graviga*, in which the anterior pedal gland comprises three or four cells, shows no line of demarcation between the cells of the mid-ventral line and those more laterally placed; and even if all stages in the development of this organ were present it is doubtful if it would afford convincing evidence that the ventral fold is a foot with a long ancestral history to those opposed to such a view. Thiele, Plate, and Nierstrasz admit that the fold is an organ concerned in the function of locomotion, but that it, with the anterior and posterior pedal glands, is the homologue of the foot of other molluscs is vigorously denied. To them the organ in question has had an independent origin, and where the furrow stops short of the branchial chamber we have a primitive state of affairs. As a matter of fact the groove passes into the branchial chamber in the larger number of neomenians I have studied, and has led me to suspect that at least a portion of this last named space may

be a true mantle cavity, though at present there is no more actual proof for such a view than for the one which considers it to be an anal space. In my opinion this fold, lying in the mid-ventral line and supplied with two glands, holding essentially the same position as the glands and creeping surface in the young *Chiton*, is a true foot, the homologue of the *Chiton* foot, and has been derived from a common ancestor. In the *Chaetodermatidae* there are few traces of its existence; in the *Neomeniina* it varies from an exceedingly small organ to one relatively wide and comprising several folds, but so far as I can judge these are secondary features having to do solely with modifications within the group.

That the ventral nerve cords cannot be considered pedal ganglia because they innervate the ventral side of the body as well as the ventral fold, and in this respect are unlike other molluscs, appears to me inconclusive evidence. The supraoesophageal ganglia in both molluscs and annelids are probably derived from homologous groups of cells of the head vesicle, and there is a strong probability that the anterior pair of ventral or suboesophageal ganglia in the annelids is the counterpart of the pedal ganglia of molluscs, the repetition of the ventral ganglia in the annelid being correlated with metameric segmentation. The ventral ganglia of annelids innervate the ventral surface, the entire body wall in fact, but with the development of the mantle and its associated complex in the molluscs a new set of ganglia, the pallial, appeared which innervate these typically molluscan organs. Whether this theoretical view is accepted or not it is certainly true that the ventral surface of the body of the molluscan ancestor, before a definite creeping surface became differentiated, was innervated and continues to be innervated whether the foot includes the entire ventral side of the body or not. Where the foot is small, as in the modern *Solenogastre*, and the body wall continues to form a portion of the under surface both continue to be supplied by this ventral set of nerves. Where the foot constitutes the entire ventral side of the body it alone is so supplied.

The broader features of the nervous system have been described in the Pacific report, and the study of the various species in the present collection merely confirms the general belief that in the *Solenogastres* it is reducible to one fundamental plan. In every case the brain is attached to three connectives, the lateral, pedal, and labiobuccal, and anteriorly develops nerves which pass into ganglionic masses (precerebral ganglia) in close proximity to the brain (*Chaetodermatina*) or attached to the bases of the atrial cirri (*Noemeniina*). The lateral and pedal cords course to the posterior end of the body where they

may unite directly or become closely associated by means of unusually heavy connectives. At frequent intervals the pedal cords are united by commissures, while an approximately similar number of connectives unite them with the lateral ganglia. These last named elements are united posteriorly by a heavy suprarectal commissure. The labiobuccal connectives pass to ganglia in the neighborhood of the radula, which are united by a ventral commissure. A dorsal commissure has also been demonstrated in certain species of neomenians (for example, *Dorymenia acuta* and *Strophomenia scandens*) arising from the labiobuccal ganglia or on the labiobuccal connectives. A second ventral commissure may also exist. In a few species of both suborders a subradular system has been demonstrated with ganglia, commissure and connective uniting them with the labiobuccal ganglia.

With these general features in mind the innervation of the various regions of the body will now be described, the description being based solely upon data derived from the study of species I have personally examined. In the Chaetodermatina the nerves from the great precerebral ganglionic masses attached to the anterior surface of the brain innervate the frontal sense organ and the anterior end of the digestive tract. Nerves from the lateral cords, and in some instances from the latero-pedal connectives, attach to the somatic musculature dorsally and laterally, while fibres from the pedal cords pass to the more ventral portions of the body. In the posterior end of the animal the ventral section of the cloacal wall and the adjacent region of the body wall are supplied with nerves originating at the posterior end of the united lateral and pedal cords. The ventral gill retractor and the ventral half of each gill is supplied with a nerve from the ventral side of the suprarectal commissure, while the dorsal half of the gill is penetrated by a nerve arising close to the mid line on the dorsal side of the suprarectal commissure. Another pair of nerves, originating on the dorsal side of this same commissure but more laterally situated, spread over the dorsal cloacal wall and the neighboring portions of the body wall probably including the dorso-terminal groove. In *Chaetoderma hawaiiense* a nerve from the suprarectal commissure, in the mid line, has been followed into the tissue surrounding the rectum. Nerves from the labiobuccal ganglia extend posteriorly along the wall of the fore gut, and in *Chaetoderma eruditum* have been followed as far as the stomach. The subradular organ is supplied with nerves from the subradular ganglia.

In the Neomeniina the six nerves leaving the anterior surface of the brain are in part distributed to ganglia, about the bases of the cirri, from which deli-

cate fibres pass into the cirri themselves. Other branches of these same cerebral nerves, though apparently independent of the atrial ganglia, pass to the anterior end of the body where they doubtless innervate the body wall including the hypodermis. In *Pachymenia abyssorum* and *Dorymenia acuta* the body wall of the anterior end of the body (and possibly the atrial ganglia, cirri, and atrial ridges) is also supplied with nerves from the anterior end of the lateral ganglia. In *Dorymenia acuta* nerves from the anterior end of the pedal cords and from each anterior latero-pedal connective have been followed to the external atrial ridge. The pharynx is supplied, at least in part, with nerves from the labio-buccal ganglia or from some of the labiobuccal connectives, and in *Dorymenia acuta* a pair of small nerves, having an independent origin from the sides of the brain, have been followed a short distance into the pharyngeal musculature. In *Alexandromenia agassizi* and *Pachymenia abyssorum* the walls of the outlet of the anterior pedal gland are furnished with nerves from the anterior end of the pedal ganglia.

The dorsal side of the body is supplied with nerves from the lateral cords, the sides are furnished with branches from the lateral and pedal ganglia and to some extent by delicate offshoots from the latero-pedal connectives, while the ventral surface is innervated by nerves from the pedal cords. In rare instances slender branches from the pedal commissures have been followed into the foot or ventral fold. In the posterior end of the body the terminal section of the shell gland or ventral section of the coelomoducts in *Strophomenia ophidiana* and *Alexandromenia agassizi* are supplied with nerves from the posterior end of the pedal ganglia or from the posterior latero-pedal connective in *Drepanomenia vampyrella*. Nerves to the pericardial wall and heart in *Strophomenia ophidiana* have their origin in the posterior end of each lateral ganglion. Nerves from the same source enter the gill lamellae in *Pachymenia abyssorum* and *Alexandromenia agassizi* which in the first named species at least are also innervated by other nerves from the posterior end of the pedal ganglia. The body and cloacal walls are furnished with nerves from the posterior end of the pedal and lateral cords and in *Drepanomenia vampyrella* an additional supply originates in the most posterior latero-pedal connective. In several species the suprarectal commissure gives off one nerve (two in *Strophomenia regularis*) which enters the dorso-terminal sense organ. In *Alexandromenia agassizi* the nerve to the sense organ is a relatively small offshoot of a branch having the usual attachment to the suprarectal commissure, but more posteriorly it passes into some of the more dorsally placed gill lamellae.

Regarding the fragmentary knowledge we have of the embryonic development of the Solenogastres and the light which this throws on the question of the primitive characters of the group, it must be admitted that very little conclusive evidence has appeared. In an earlier paper (Heath, 1911) it was shown that the Chiton and annelid in their development up to the trochophore stage follow practically the same course. The great test or modified velum in the Solenogastre larva cannot therefore be looked upon as a primitive mark; nor can the posterior invagination which may represent a dorso-terminal sense organ against which the nerve band abuts. Unfortunately we have no conclusive evidence regarding the presence of a true shell nor any data relating to the form and size of the foot. Whether adult characters are to be considered primitive or secondarily modified must accordingly largely rest upon comparative anatomical studies and the personal factor in interpreting such evidence.

As Nierstrasz has maintained the various species of Solenogastres show a truly surprising amount of variation, and while it is possible to find a fundamental plan upon which all are constructed it is most difficult to decide which features are the most primitive. Personally I am strongly of the belief that the ancestral Solenogastre was provided with a mantle cavity containing a pair of ctenidia and the openings of the coelomoducts and digestive tract, and a creeping surface or foot provided with two sets of glands. Whether a shell was present or absent cannot be decided. The digestive tract was provided with a typical radula, dorsal and ventral salivary glands, while the mid-gut lacked a clearly defined digestive gland. The heart, in the posterior end of the body, communicated on one hand with a sinus from the ctenidia and in the other direction connected with the dorsal aorta, which supplied the gonad and opened through a septum limiting the head cavity. This septum was also perforated ventrally to allow the flow of blood into the visceral cavity and probably a ventral sinus from which it passed to the ctenidia. The coelom comprised a genital section opening into the pericardium, which in turn communicated with the exterior by means of two simple, distinct coelomoducts. The nervous system, having essentially the same configuration as it now possesses, was probably more diffuse.

If such indeed does represent the general plan of the ancestral Solenogastre then it follows that the members of the Chaetodermatidae are highly modified in most respects. They have retained their ctenidia, their relatively simple coelomoducts, and in *Limifossor* there is an anterior septum and a well-developed radula. In the neomenians the foot and glands still persist, and in certain

species a typical radula is present together with dorsal and ventral salivary glands and a diffuse digestive gland. In the posterior end of the body great coenogenetic changes have ensued. The coelomoducts are usually united, seminal receptacles have appeared, and a highly glandular epithelium has developed at least in the terminal section. Penial spines and branchial folds are, in my opinion, likewise recent developments. Where the spines imbedded in the cuticle investing the body develop from a single matrix cell it probably represents the most primitive condition, but since certain neomenians develop some of their spicules in the same general fashion as the Chitons do in part it appears probable that both modes prevailed in the ancestral Solenogastre.

As noted above the Solenogastres are a highly variable group, and such genera as *Alexandromenia*, *Pachymenia*, and *Neomenia* appear to me to stand among the most highly modified members of the order Aplacophora. The Chitons on the other hand are a remarkably conservative group, the differences between the most diversified genera, such as *Cryptochiton*, *Chitonellus*, and *Ischnochiton*, being far less than those differentiating *Limifossor* and *Chaetoderma* belonging to the same family. When I made the claim that the Chitons represent the most archaic type of modern mollusc I had in mind the highly modified Solenogastres just noted which appear to me to have departed more widely from the ancestral mollusc than any of the Chitons. It doubtless is possible to select a character here and there from the various species of known Solenogastres and produce a list of primitive features of greater length and more importance than in the case of the Chitons. On such a basis of selection the Solenogastres may be considered to be the more primitive group, but where a single species of Solenogastre (especially from one of the genera noted above) is compared with a single species of Chiton it appears to me that more primitive features will be found to exist in the last named. However this is not a matter upon which I would lay great stress since it appears to rest upon much less conclusive evidence than does the theory whereby the Solenogastres are considered to be more closely related to the Chitons than to any other group of molluscs.

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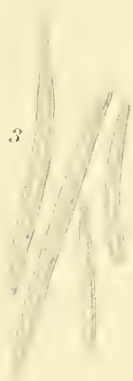
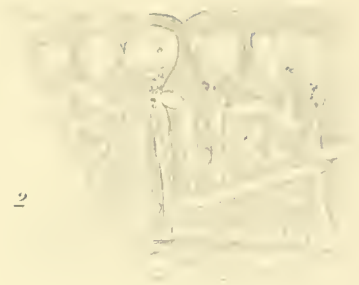
EXPLANATION OF THE PLATES.

a	anus	oe	oesophagus
aor	aorta	pe	pedal ganglion
ap	anterior pedal gland	peg	precerebral ganglion
b	brain	pem	pericardium
be	buccal commissure	ph	pharynx
bg	labiobuccal ganglion	pl	lateral ganglion
br	gill	ps	pedal sinus
brn	nerve to gill	r	radula
c	intestinal coecum	re	seminal receptacle
cl	cloacal chamber	rs	radular support
co	cloacal coecum	s	anterior vertical septum
cp	coelomoduct	se	subradular commissure
da	dorsal aorta	sg	ventral salivary gland
dsg	dorsal salivary gland	sgl	shell gland
fo	buccal plate	sn	subradular ganglion
gl	glands of pharynx	so	sense organ
gon	gonad	sp	spicule
ht	heart	sr	dorsal gill retractor
int	intestine	sro	subradular organ
lbc	labiobuccal connective	sto	stomach
liv	liver	sv	seminal vesicle
m	mouth	vr	ventral gill retractor
n	nerve to buccal plate	vs	ventral diaphragm

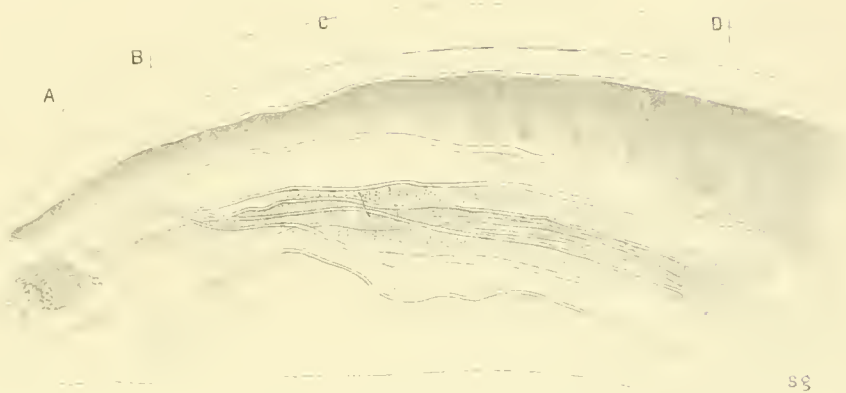
PLATE 1.

PLATE 1.

- Fig. 1. Two individuals of *Strophomenia agassizi* in the act of copulation; the posterior ends in contact near left side of figure. $\times 6$.
Fig. 2. Hypodermis and papillae in head region. $\times 135$.
Fig. 3. Spicules from middle of body. $\times 100$.
Fig. 4. Reconstruction of anterior end of body.
Fig. 5. Reconstruction of posterior end of body.
Fig. 6. Section across outlet of anterior pedal gland of *Neomenia verrilli*.



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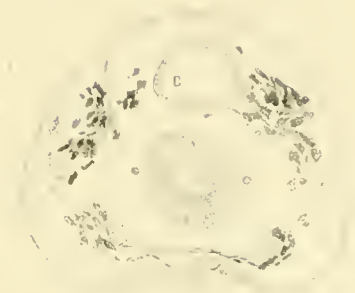
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PLATE 2.

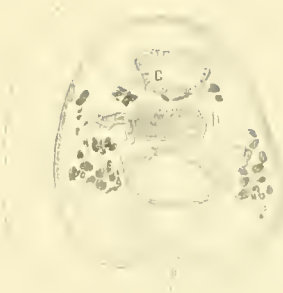
PLATE 2.

- Fig. 1. *Strophomenia agassizi*. Section along line C of fig. 4, pl. 1.
- Fig. 2. Same along line B of fig. 4, pl. 1.
- Fig. 3. Same along line A of fig. 4, pl. 1.
- Fig. 4. Section along line H of fig. 5, pl. 1.
- Fig. 5. Section along line D of fig. 4, pl. 1.
- Fig. 6. Section along line F of fig. 5, pl. 1. (One third reduced).
- Fig. 7. Same along line G of fig. 5, pl. 1.
- Fig. 8. Same along line E of fig. 5, pl. 1. $\times 360$.
- Fig. 9. *Nierstrassia fragile*. Ventral fold. $\times 360$.
- Fig. 10. Section through radula. $\times 555$.

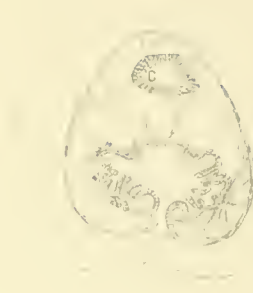
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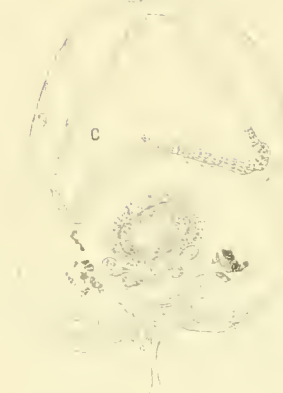
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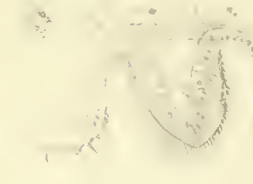
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PLATE 3.

PLATE 3.

- Fig. 1. Reconstruction of posterior end of body of *Neomenia verrilli*. pgl. penial gland.
Fig. 2. Section through posterior end of body along line of D of fig. 1.
Fig. 3. Section through seminal vesicle.
Fig. 4. Reconstruction of anterior end of body.
Fig. 5. Section through accessory penial spines and glands. $\times 85$.
Fig. 6. Lateral view of entire animal. $\times 2$.
Fig. 7. Section through accessory penial spines and glands. $\times 46$.
Fig. 8. Hypodermis and papillae. $\times 190$.

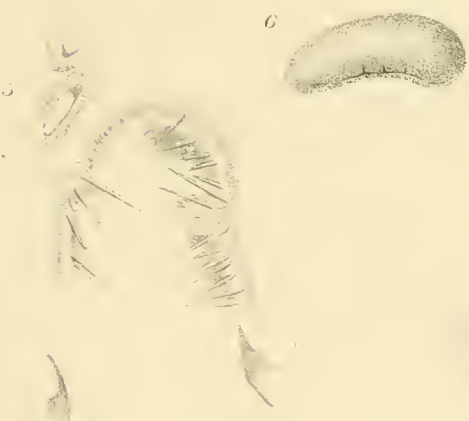
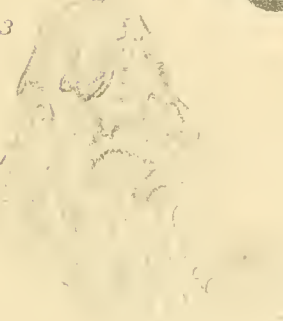


PLATE 4.

PLATE 4.

- Fig. 1. *Neomenia verrilli*. Section through penial gland and junction of dorsal and ventral limbs of coelomoduct. $\times 85$.
- Fig. 2. Section through posterior end of body along line E of fig. 1, pl. 3.
- Fig. 3. Section through pharynx along line B of fig. 4, pl. 3.
- Fig. 4. Section through pharynx along line C of fig. 4, pl. 3.
- Fig. 5. Cloacal folds and attached glands. $\times 215$.
- Fig. 7. Section through brain along line A of fig. 4, pl. 3.
- Fig. 8. Section through distal end of penial spine, sheath, and attached muscles. $\times 29$.
- Fig. 6. *Proneomenia acuminata*. Section through middle of heart. $\times 85$.
- Fig. 9. Teeth to left of mid line.
- Fig. 10. Section through pharynx (ph) at level of subradular organ.
- Fig. 11. Section along line B of fig. 1, pl. 5.
- Fig. 12. Section along line E of fig. 5, pl. 5.

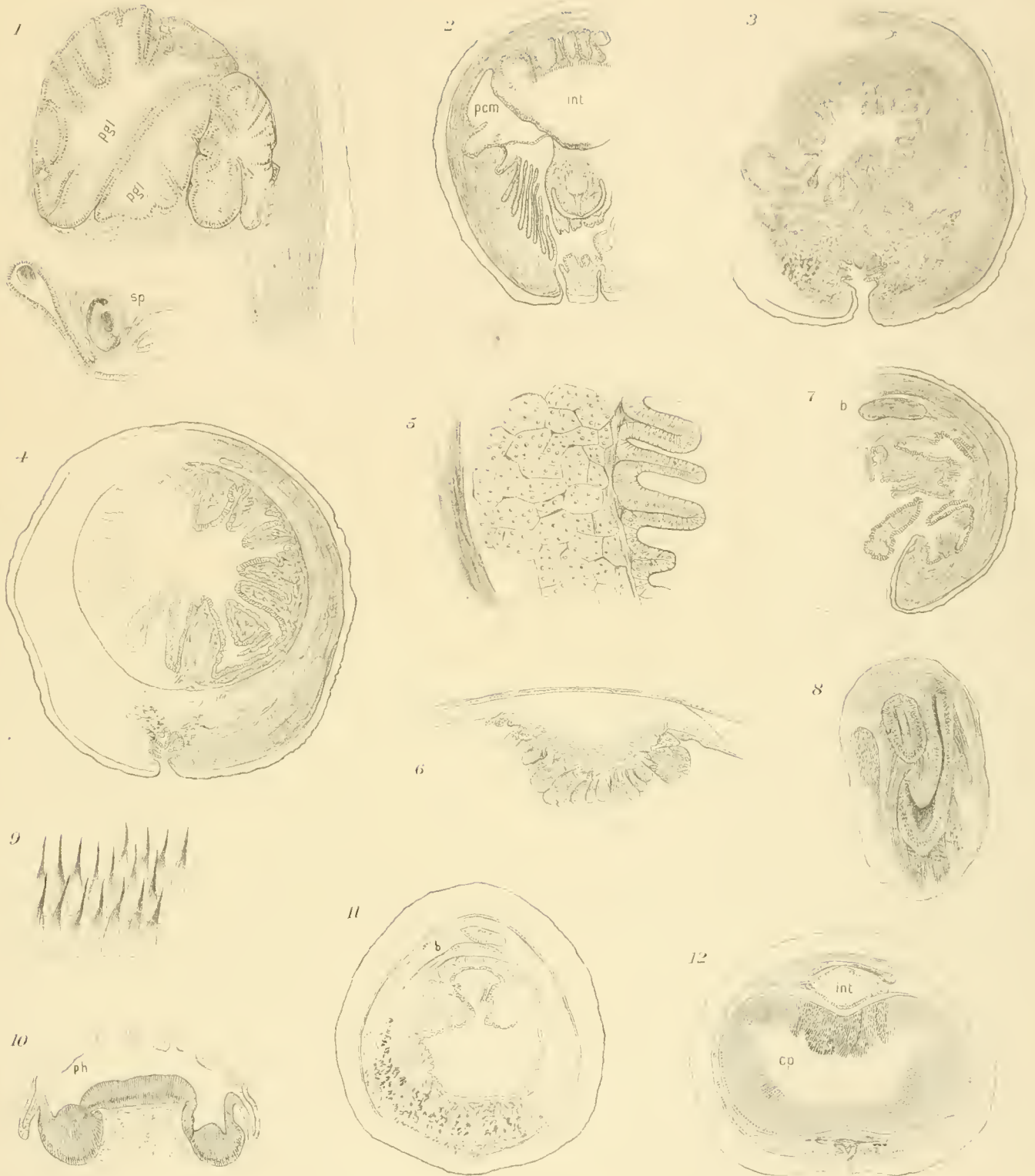


PLATE 5.

PLATE 5.

- Fig. 1. Reconstruction of anterior end of body of *Proneomenia acuminata*.
- Fig. 2. Section through pharynx along line C of fig. 1.
- Fig. 3. Entire animal. $\times 2$.
- Fig. 4. Spines from sides of body. $\times 100$.
- Fig. 5. Reconstruction of posterior end of body. Sg, shell gland.
- Fig. 6. Hypodermis and papillae. $\times 190$.
- Fig. 7. Section through pharynx (ph) at level of subradular ganglia (srg) above which are ducts of the ventral salivary glands.
- Fig. 8. Section along line F of fig. 5 int, intestine.
- Fig. 9. Section along line A of fig. 1.
- Fig. 10. Section along line D of fig. 5. da, dorsal aorta; ht, heart; sr, seminal receptacle.
- Fig. 11. Section through cloacal chamber along line G of fig. 5.

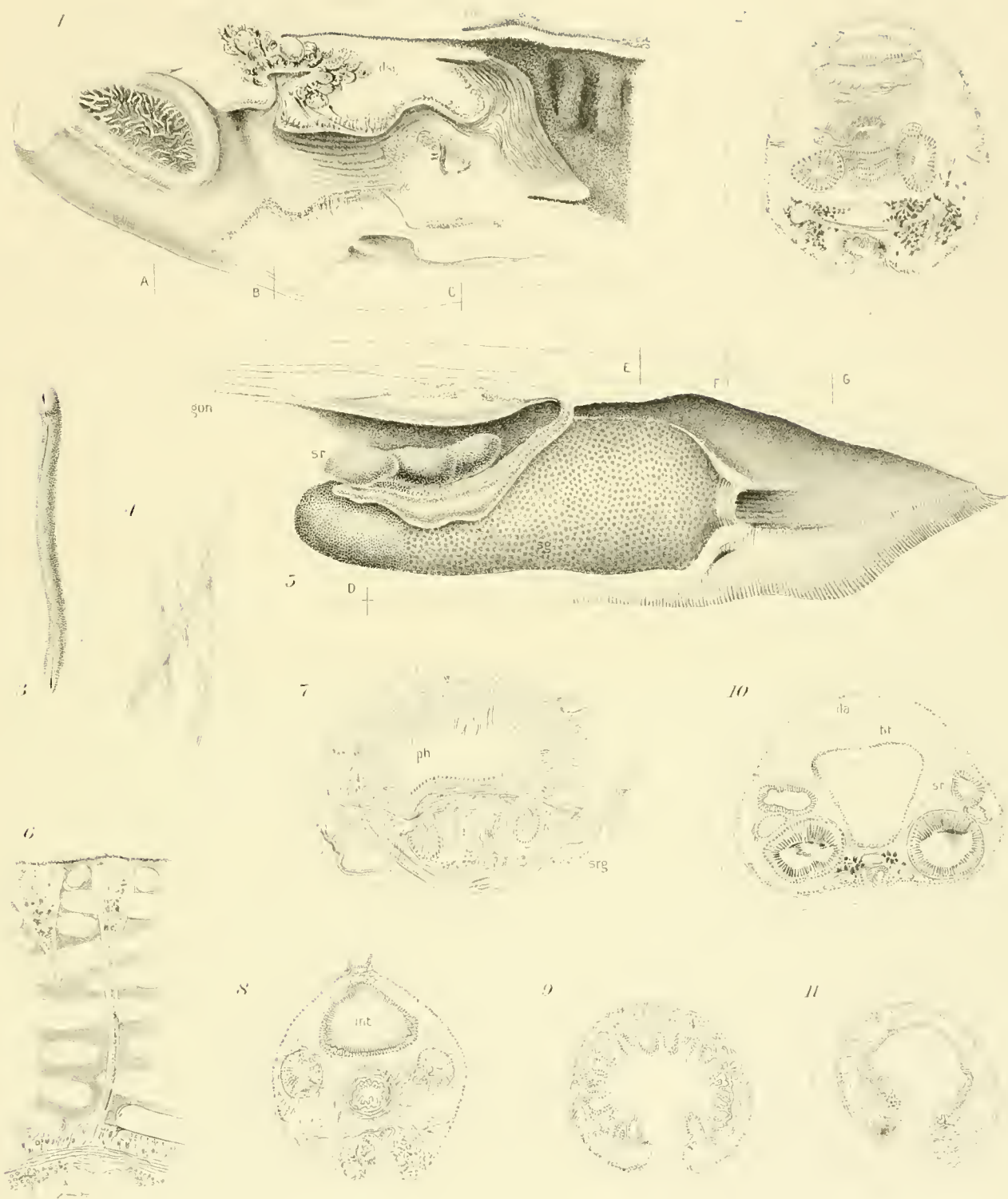


PLATE 6.

PLATE 6.

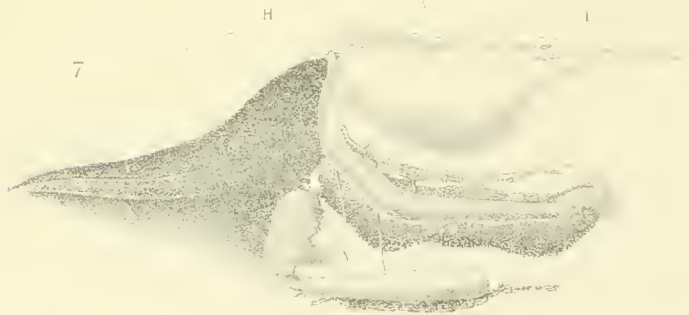
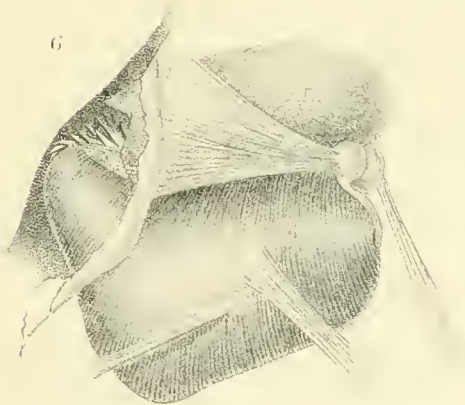
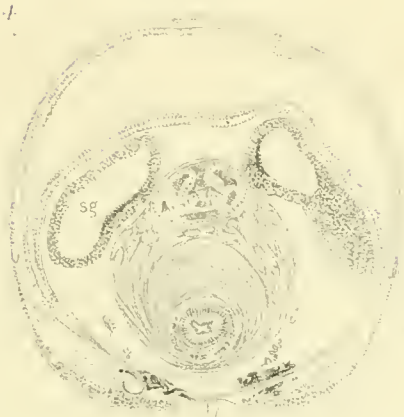
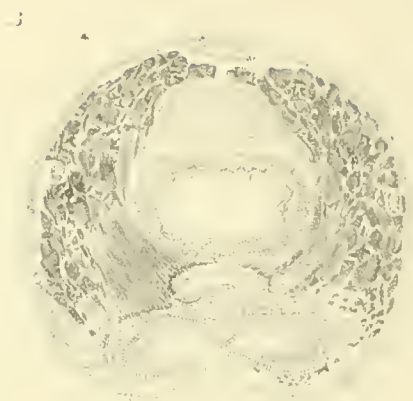
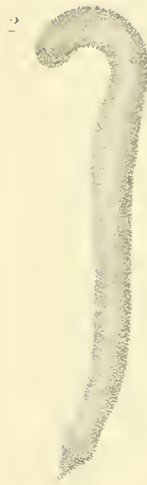
- Fig. 1. Entire animal of *Nierstrassia fragile*. $\times 13$.
Fig. 2. Hypodermal layer. $\times 800$.
Fig. 3. Reconstruction of anterior end of body.
Fig. 4. Section through posterior end of body along line F of fig. 5.
Fig. 5. Reconstruction of posterior end of body.
Fig. 6. Section through posterior end of body along line C of fig. 5.
Fig. 7. Same along line D of fig. 5.
Fig. 8. Section through region of brain along line A of fig. 3.
Fig. 9. Longitudinal section through brain and anterior end of alimentary canal. $\times 180$.
Fig. 10. Section through posterior end of body along line E of fig. 5.
Fig. 11. Posterior end of body, ventral view.



PLATE 7.

PLATE 7.

- Fig. 1. *Nierstrassia fragile*. Cross section at level of B of fig. 3, pl. 6.
Fig. 2. *Dorymenia peroneopsis*, entire animal. $\times 3$.
Fig. 3. Section through brain at level of line B of fig. 5, pl. 7.
Fig. 4. Section through anterior end of body corresponding to line E of fig. 5, pl. 7. Salivary glands in natural position.
Fig. 5. Reconstruction of anterior end of body. The main portion of the ventral salivary gland has been shifted ventrally to show radular mechanism.
Fig. 6. Reconstruction of radular apparatus.
Fig. 7. Reconstruction of posterior end of body.



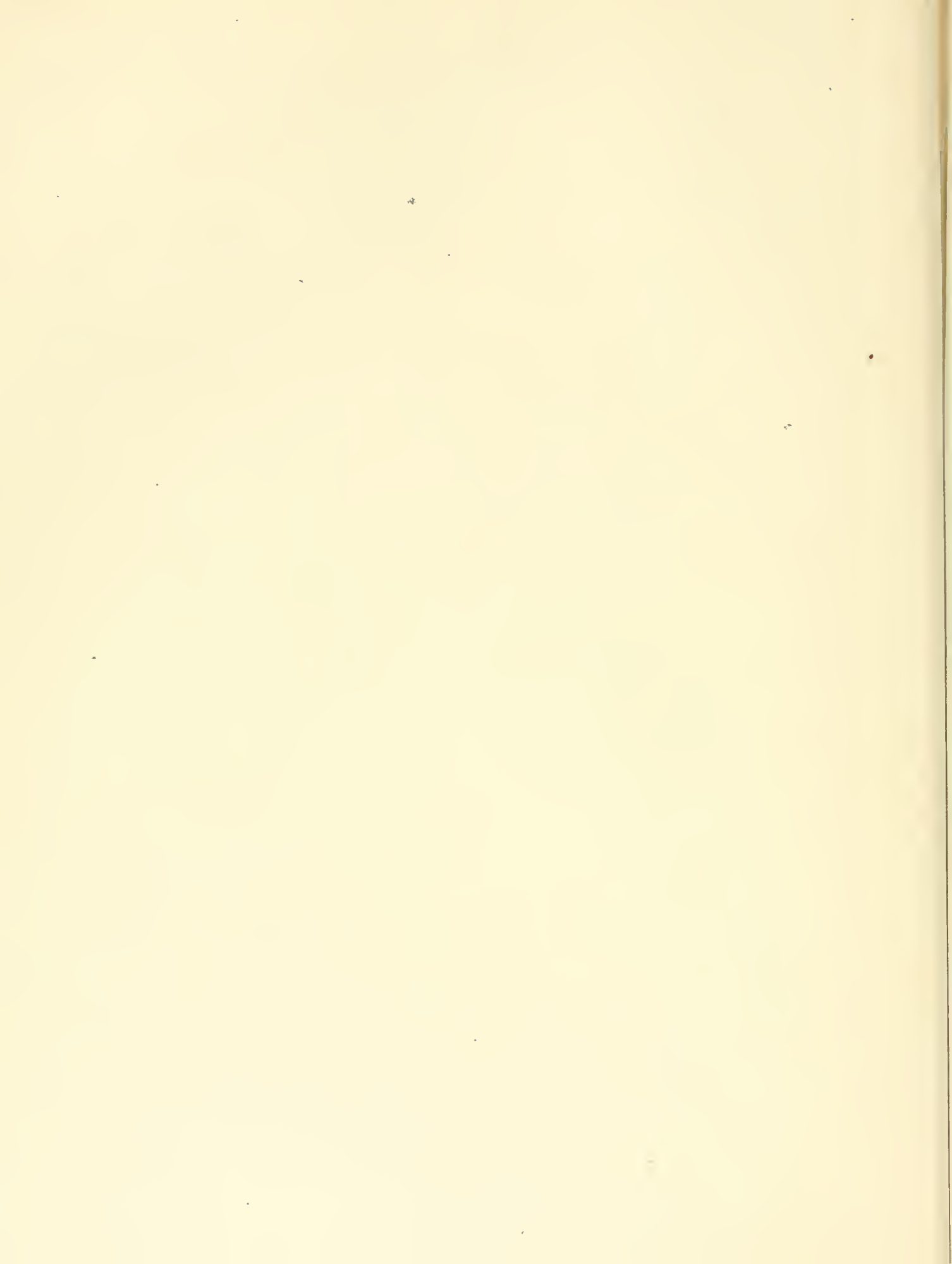


PLATE 8.

PLATE 8.

- Fig. 1. *Dorymenia peroneopsis*. Section through posterior end of body along line G of fig. 7, pl. 7.
Fig. 2. Spines from side of body. $\times 190$.
Fig. 3. Section along line H of fig. 7, pl. 7.
Fig. 4. Section along line A of fig. 5, pl. 7.
Fig. 5. Section along line C of fig. 5, pl. 7.
Fig. 6. Section along line F of fig. 7, pl. 7.
Fig. 8. Section along line D of fig. 5, pl. 7.
Fig. 9. Papilla and hypodermis, head region. $\times 255$.
Fig. 7. Cross section of pharyngeal (salivary) gland of *Chaetoderma caudatum*. $\times 91$.
Fig. 10. Section close to junction of pharynx and mid-gut. $\times 88$.
Fig. 11. Section slightly anterior to forward border of pericardium showing alimentary canal, two lateral gonoducts and dorsal aorta.
Fig. 12. Section through mid-gut or stomach.

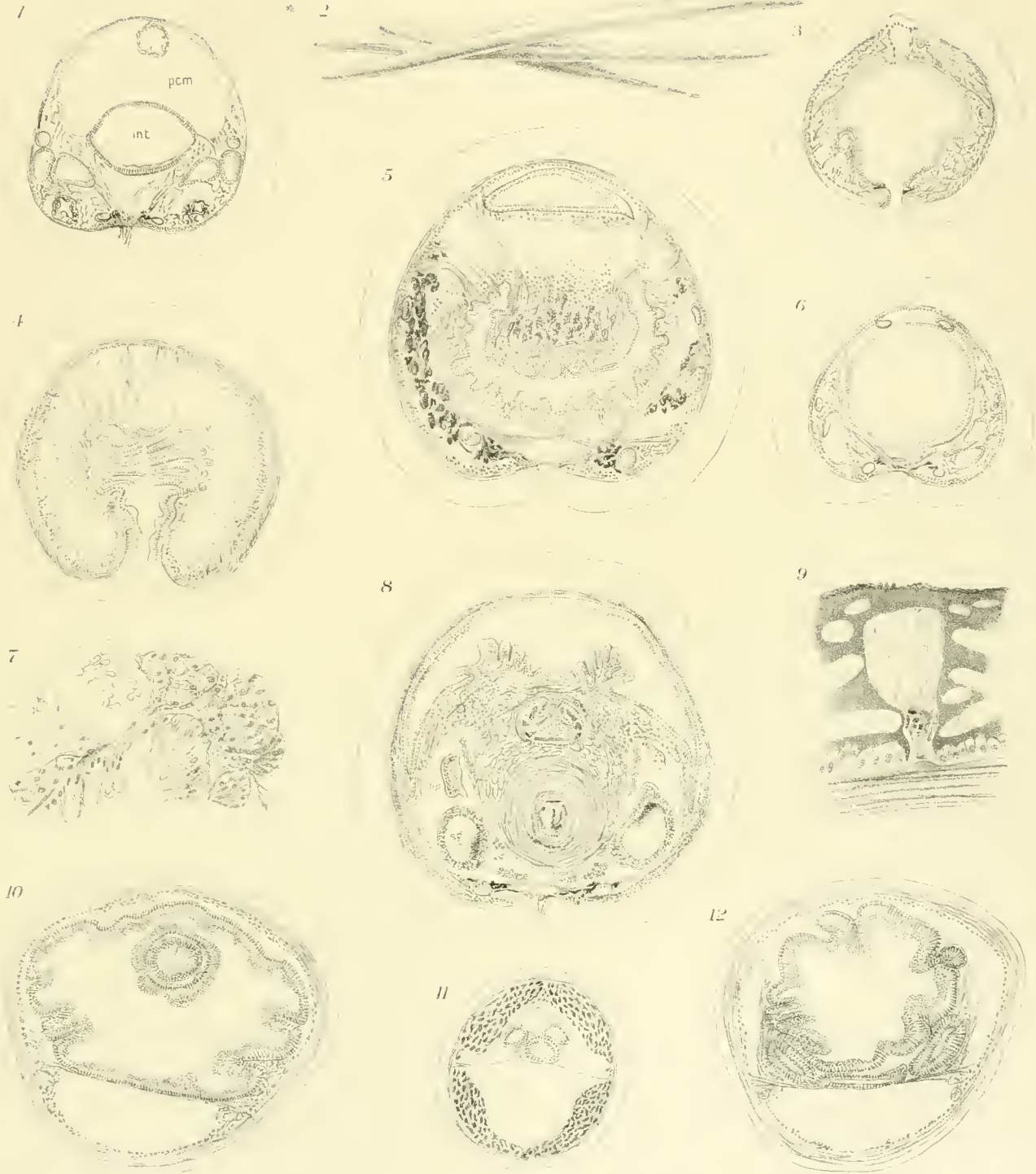


PLATE 9.

PLATE 9.

- Fig. 1. *Chaetoderma caudatum*, entire animal. $\times 8$.
- Fig. 2. Head region of same specimen. $\times 12$.
- Fig. 3. Side view of another specimen. $\times 12$.
- Fig. 4. Anterior view of same animal as fig. 1. $\times 12$.
- Fig. 5. Section at level of radula. $\times 88$.
- Fig. 6. Section through pericardium and coelomoducts.
- Fig. 7. Section at level of external coelomoduct openings.
- Fig. 8. Section at level of brain.
- Fig. 9. Hypodermis of prothorax. $\times 360$.
- Fig. 10. Junction of stomach and liver.
- Fig. 11. Spines from mid section of body. $\times 190$.
- Fig. 14. Section through outlets of pericardium into coelomoducts.
- Fig. 12. Two specimens of *Chaetoderma lucidum*. $\times 4$.
- Fig. 13. Section through a pharyngeal gland. $\times 330$.
- Fig. 15. Spines. $\times 146$.
- Fig. 16. Cross section of metathorax. $\times 46$.
- Fig. 17. Section through dorso-terminal sensory groove. $\times 190$.
- Fig. 18. Cross section at junction of pro- and metathorax.

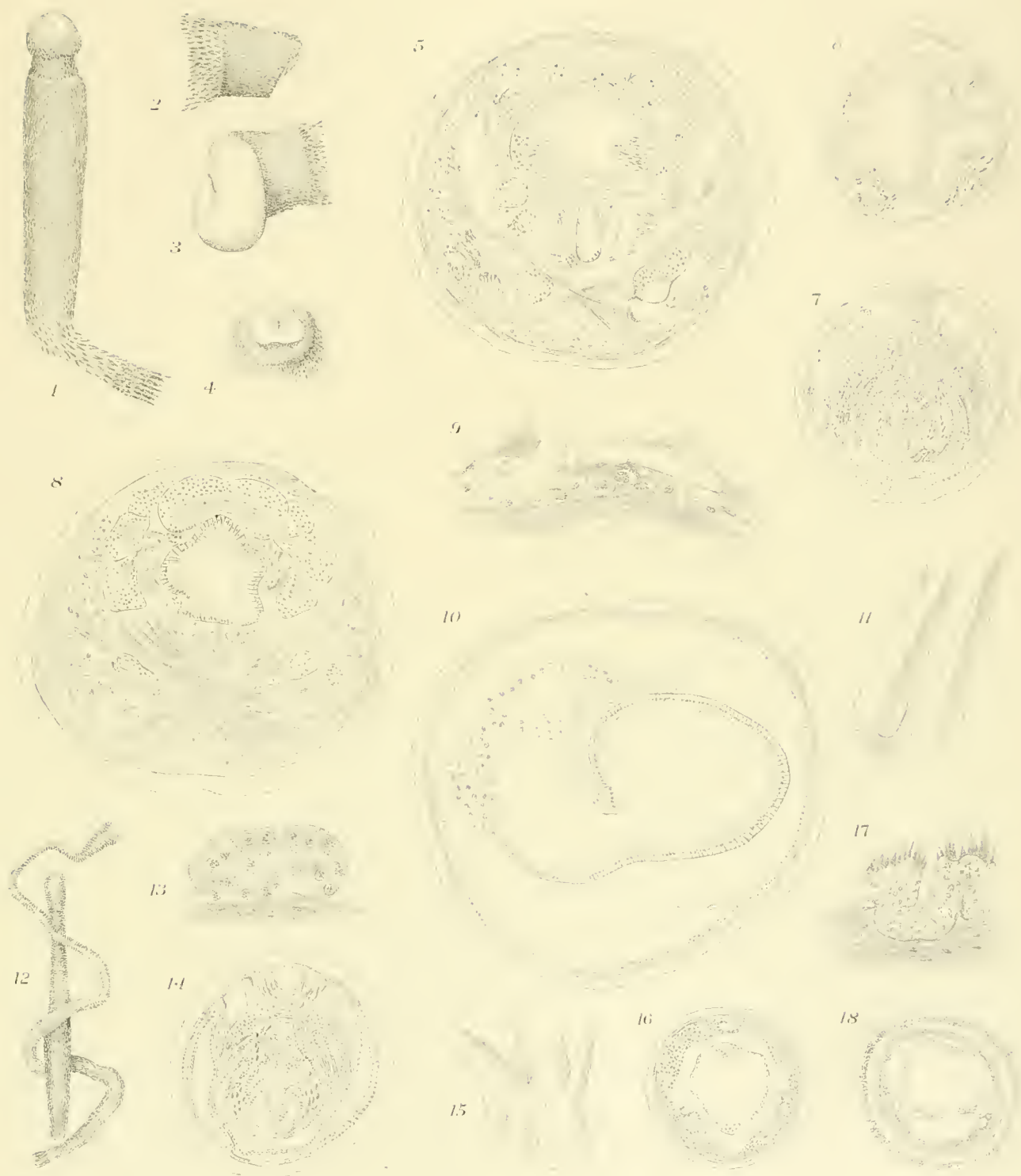


PLATE 10.

PLATE 10.

- Fig. 1. *Chaetoderma lucidum*. Section through head at level of radula. $\times 46$.
- Fig. 2. Cross section through brain.
- Fig. 3. Section through posterior end of body at level of coelomoduct outlets.
- Fig. 4. Junction of digestive gland and midgut or stomach.
- Fig. 5. Junction of pharynx and stomach.
- Fig. 6. Section at level of suprarectal commissure.
- Fig. 7. Gastric epithelium, showing supposed intercellular bridges.
- Fig. 11. Anterior end.
- Fig. 8. *Chaetoderma bacillum*, entire animal. $\times 7$.
- Fig. 9. Section through anterior end at level of radula. $\times 46$.
- Fig. 10. Section at level of brain.
- Fig. 12. Section through junction of pro- and metathorax.
- Fig. 13. Portion of hypodermal layer.
- Fig. 14. Section at level of posterior end of heart.

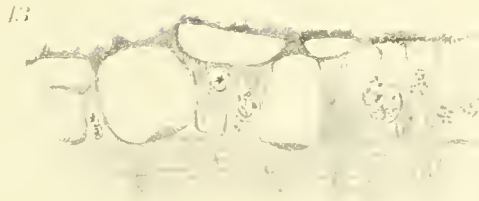
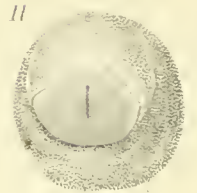
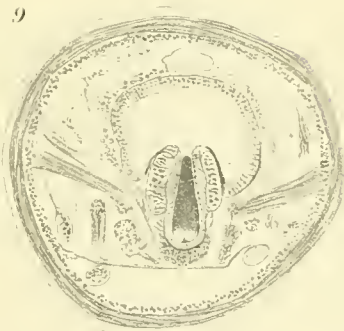
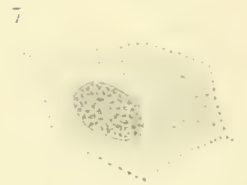
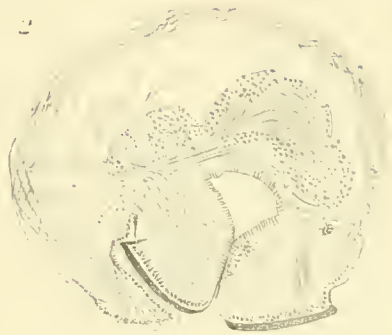
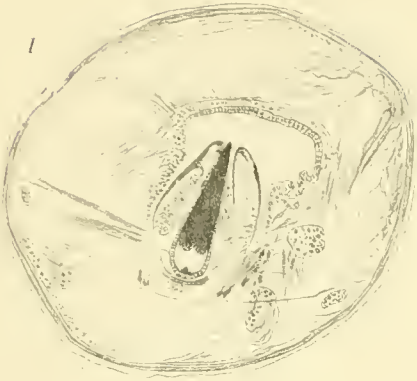


PLATE 11.

PLATE 11.

- Fig. 1. *Chaetoderma bacillum*. Section near junction of pharynx and stomach.
- Fig. 2. Section at level of suprarectal commissure.
- Fig. 3. Section at level of coelomoduct openings to exterior.
- Fig. 4. Spicules from middle of body. $\times 146$.
- Fig. 6. *Chaetoderma bacillum*. Anterior end.
- Fig. 7. Section slightly anterior to opening of gut into cloaca.
- Fig. 5. *Chaetoderma squamosum*, entire animal. $\times 3$.
- Fig. 8. Section slightly anterior to junction of pro- and metathorax. $\times 35$.
- Fig. 9. Spines from mid section of body. $\times 91$.
- Fig. 10. Cross section of body at level of radula.
- Fig. 11. Section at level of brain.
- Fig. 12. Section about level of middle of pericardium.
- Fig. 14. Section near junction of pharynx and stomach.
- Fig. 15. Section through anterior end of metathorax.
- Fig. 16. Section at level of dorso-terminal groove and coelomoduct outlets.
- Fig. 17. Junction of pro- and metathorax.
- Fig. 13. Anterior end of young specimen of *Chaetoderma vadorum*.



PLATE 12.

PLATE 12.

- Fig. 1. *Chaetoderma vadorum*. Section through anterior end at level of radula.
Fig. 2. Section through one group of pharyngeal glands. $\times 255$.
Fig. 3. Spines from middle of body. $\times 146$.
Fig. 4. Oblique section through metathorax.
Fig. 5. Section through middle of prothorax.
Fig. 6. Section through brain.
Fig. 7. Section at union of pharynx and stomach.
Fig. 8. Section through anterior end of metathorax.
Fig. 9. Section through pharynx slightly behind the radula.
Fig. 10. Section through junction of stomach and liver.
Fig. 11. Section through anterior end of pericardium.
Fig. 12. Same region as fig. 9 in another specimen.
Fig. 13. Section at level of openings of gut and coelomoduct into the cloacal chamber.
Fig. 14. Section through union of pro- and metathorax.
Fig. 15. Section at level of suprarectal commissure.
Fig. 16. Gland cells near mid-ventral line of body in preabdomen. $\times 255$.
Fig. 17. Same region as in fig. 1 of another specimen.

PLATE 13.

PLATE 13.

- Fig. 1. *Chaetoderma vadorum*.
 - Fig. 2. Same species, anterior end.
 - Fig. 3. Section through dorso-terminal groove. $\times 330$.
 - Fig. 4. Section at level of brain.
 - Fig. 8. Hypodermis.
 - Fig. 5. Ovum showing male and female pronucleus of *Halomenia gravida*.
 - Fig. 6. Reconstruction of segmentation stage in the development.
 - Fig. 9. Longitudinal horizontal section through posterior end of larva of about the same stage as in fig. 11.
 - Fig. 10. Nuclei-like bodies in egg; also shown in fig. 5.
 - Fig. 11. Reconstruction of an advanced larva.
 - Fig. 12. Reconstruction of another stage about midway between those represented in figs. 6 and 13.
 - Fig. 13. Reconstruction of early stage somewhat flattened.
 - Fig. 7. Hypodermis of *Chaetoderma squamosum*. $\times 290$.
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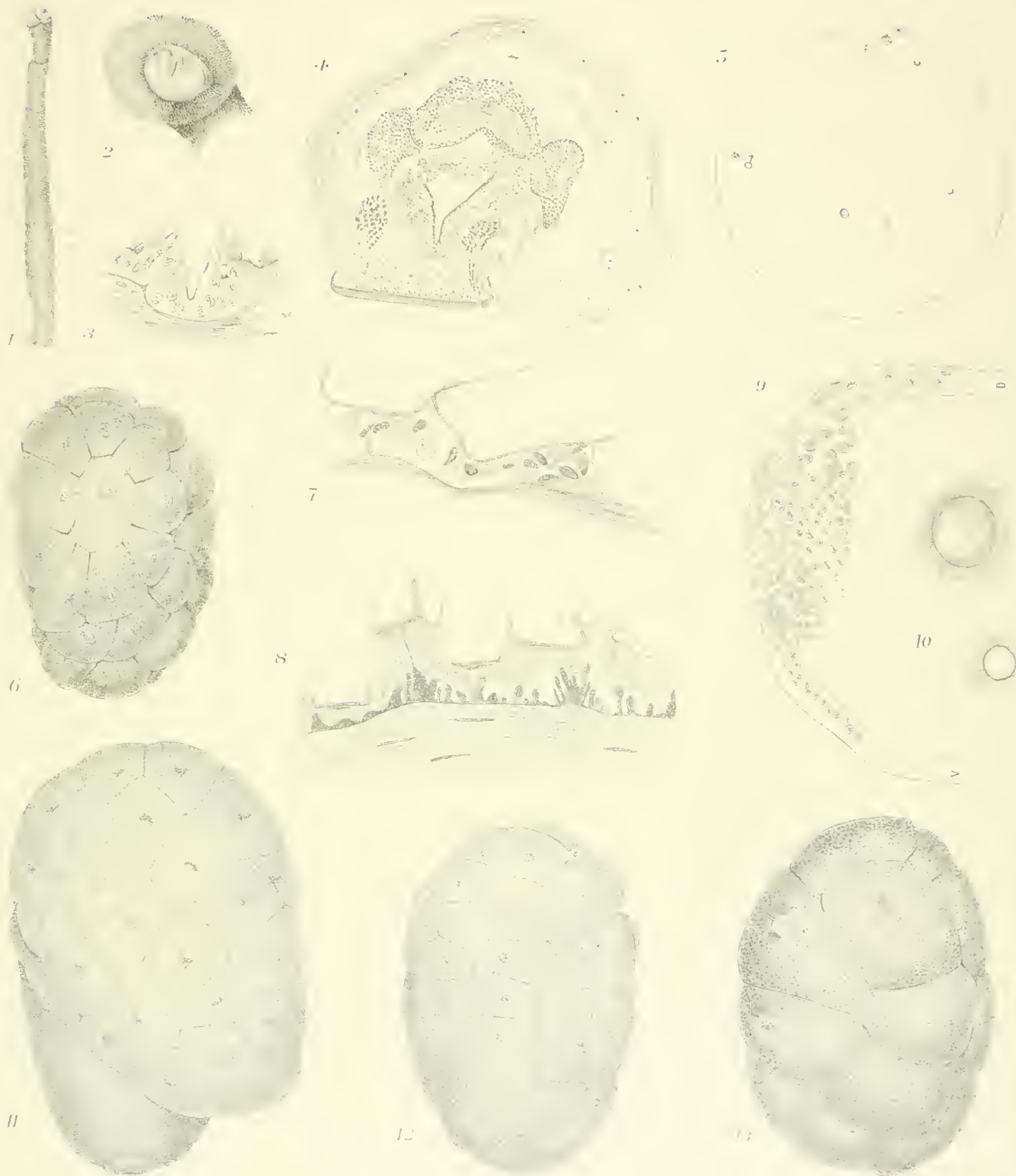


PLATE 14.

PLATE 14.

Fig. 1. Longitudinal horizontal section through posterior terminal depression in an advanced larva of *Halomenia gravida*.

Fig. 2. Same; younger than stage represented in fig. 3. $\times 330$. D, v, dorsal and ventral surfaces.

Fig. 3. Longitudinal horizontal section through larva of about the same stage as fig. 11, pl. 13.

Fig. 4. Longitudinal horizontal section through oldest larva.

Fig. 5. Next section to the one represented in fig. 1. The horizontal lines in this and fig. 1 coincide.

Fig. 6. Early stage in the development of the cerebral ganglia. $\times 360$.

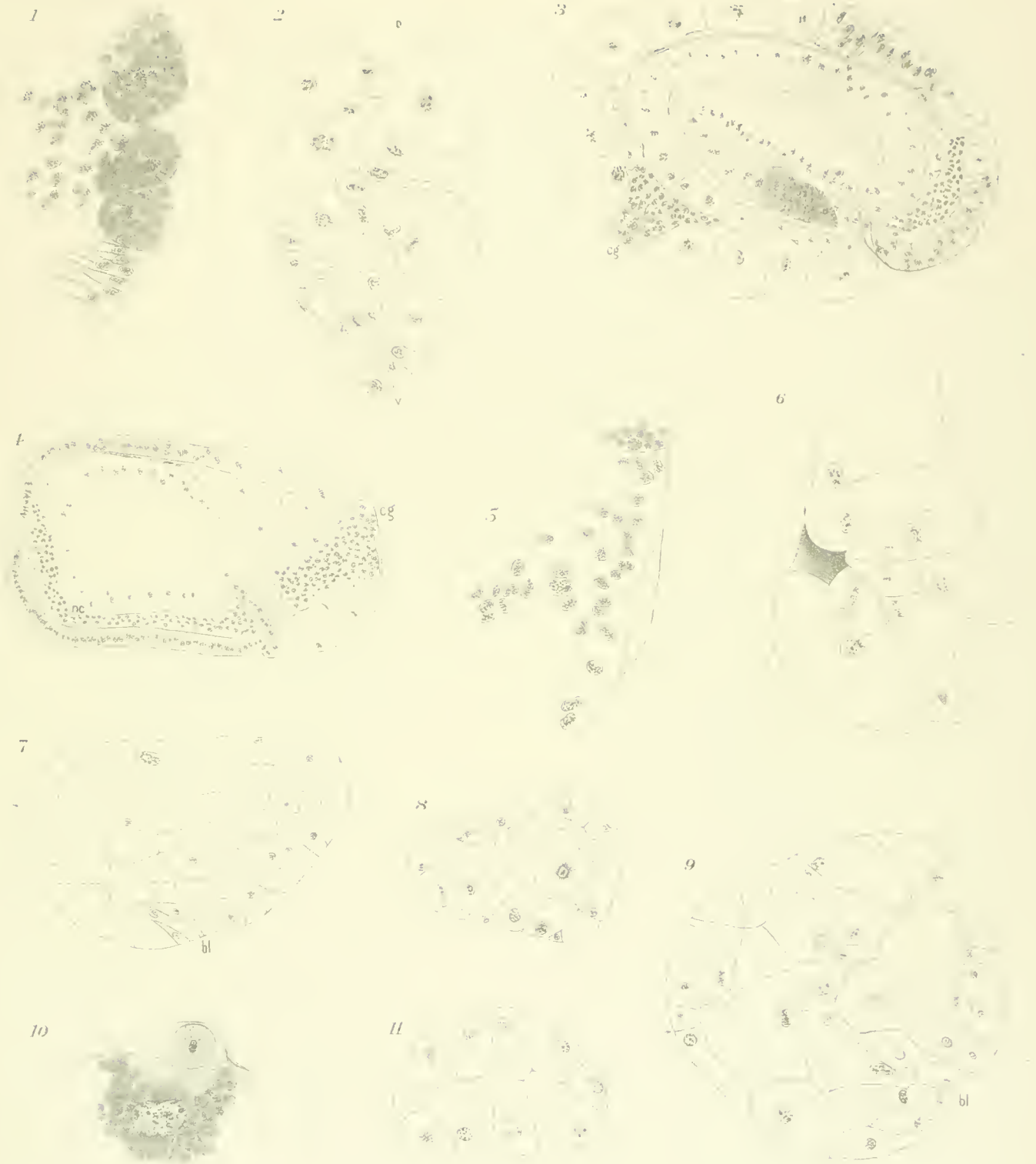
Fig. 7. Longitudinal horizontal section of about the same stage as fig. 12, pl. 13. Arrow indicates position of polar body.

Fig. 8. Longitudinal horizontal section of about the same stage as fig. 6, pl. 13. $\times 91$.

Fig. 9. Longitudinal horizontal section of about the same stage as fig. 12, pl. 13. $\times 91$. Arrow indicates position of polar body.

Fig. 10. Polar body and female pronucleus; same stage as fig. 5, pl. 13. $\times 330$.

Fig. 11. Section through larva of about the same stage as fig. 13, pl. 13.



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Vols. LV., LVII., LXII., and LXIII. of the BULLETIN, and Vols. XXXIX., XLIII., XLVII. to XLIX. of the MEMOIRS, are now in course of publication.

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